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View in Colorado Canyon of a river which has cut a channel much larger than the most extreme requirements of flood flow.

The discharge of the river at this point could be increased a hundred times over that of the greatest flood flow and yet fill only a small part of the canyon which the river has formed.

WHY RIVERS OVERFLOW.—[See page 392.]

Motion Pictures in Colors*

Various Methods by Which the Problem Has Been Attempted

MOTION pictures in colors are produced by coloring ordinary films by hand or by stencil, and also by various modifications of the three-color process of photoengraving.

Coloring by hand is a delicate and laborious operation, because of the large number and small size of the pictures. The work is usually done by women, and it requires close attention, great patience and a skilled eye. It is facilitated and expedited, and its results are improved by division of labor. Each woman applies a single color, the tint and location of which are determined by the chief colorist. The film passes over a number of ground glass tables, such as are used in retouching photographic prints.

The colors, in aqueous solution, are applied with fine brushes, in flat tints and in small quantities, which are absorbed by the gelatine, so that the film dries quickly. Despite all care and skill the color often overflows its assigned limits, but as these errors do not recur regularly in the same places in successive pictures they do not seriously injure the projection on the screen.

When only a few positive films are wanted they are always colored by hand, but when many films are required time and labor are saved by the use of stencils.

The stencils, one for each color, are cut from as many positive films, from each of which the part that corresponds to the given color is removed. For example, the sky of a landscape is cut away from the blue stencil. The cut films are soaked in hot water to remove the gelatine coating and are then ready for use as stencils.

The film to be colored is placed in contact with the stencil, so that their lateral perforations coincide, and the two films are drawn through the coloring machine by wheels having teeth which enter the perforations. In the machine the film and stencil pass either under a flexible roller saturated with the color appropriate to the stencil, or beneath a vaporizer of the air-brush type, which projects the liquid color in a fine spray. In either case the color is applied only to those parts of the film that correspond with the parts cut away from the stencil. The operation is rapid and exact.

The partially colored film is then separated from the stencil and run, with a second stencil, through a second machine which applies a second color, and the operation is repeated until all of the colors desired have been applied.

The difficulty of cutting stencils from the little pictures with the necessary precision has been surmounted by an ingenious artifice. The film to be cut is moved, picture by picture, through a frame placed beside a screen, on which the corresponding pictures of another film from the same negative are projected by a lantern. A tracing point which terminates the long arm of a pantograph is applied to the screen, and a cutting tool which terminates the short arm is applied to the film.

Fig. 3.—Kinemacolor shutter.

The pantograph is so constructed that the displacements of the cutting tool and the tracing point are proportional, respectively, to the dimensions of the film picture and its enlarged projection. The cutting tool is machine-driven and the task of the operator consists merely in tracing on the screen the outline of the parts corresponding to a given color. In this way the stencils are cut with a precision that could not be attained if the little pictures were cut by hand.

THREE COLOR PROCESSES.

Although the colors of nature are infinite in number, they can all be reduced, with respect to the impressions that they produce on the retina, to three fundamental colors: violet, green, and orange-red, by combinations of which all possible tints can be formed. The persistence of retinal impressions makes it possible to effect this combination by successive, as well as by simultaneous, presentation of the fundamental colors. Hence motion pictures in colors can be produced either by simultaneous projection, and exact superposition on the screen, of three films which separately would

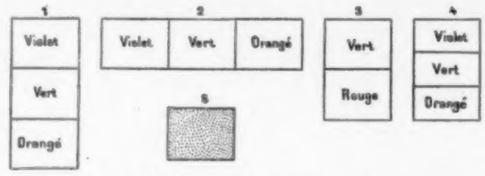


Fig. 1.—Relative lengths of films required by the various processes.

1, Three-color, successive; 2, three-color, simultaneous; 3, kinemacolor; 4, Gaumont chronochrome; 5, autochromie.

produce violet, green, and orange-red images, respectively, or by rapid projection of images which present the three colors in regularly recurring series.

In either case the synthesis of the color of any object must be preceded by an analysis, in which a separate photographic negative is made by each of the three fundamental colors. This analysis is effected by photographing the scene through violet, green and orange red screens, or ray filters.

The film exposed behind the violet filter is impressed only by the parts of the scene that contain violet, blue, or red-purple, while yellow is completely stopped by

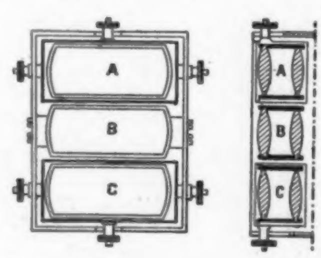


Fig. 2.—Projecting lenses. Gaumont chronochrome.

the filter. On development, therefore, this negative film will become opaque in the violet, blue, and purple parts of the scene and will remain more or less transparent in the other parts. The positive printed from this negative will, on the contrary, be opaque in the yellow and transparent in the other parts. If this positive is projected, through a sheet of violet glass, the screen will show a violet picture in which only the violet, blue and purple parts of the scene are represented.

The green and the orange of the original scene can be reproduced in the same way, by using green and orange filters, respectively, both in making the negatives and in projecting the positives. When the three colored projections are superposed or rapidly alternated the three fundamental colors are unaffected, and the other tints are reproduced by the combination of those colors in varying proportions.

At any point in the picture these proportions are determined by the relative opacities of the three negatives at that point and, consequently, by the proportions of the fundamental colors in the color of the scene at that point.

The white parts of the scene are opaque in all three negatives and transparent in all three positives, so that in the projection the three colored beams of light combine and reproduce white. The black parts are transparent in all three negatives and opaque in all three positives, so that in projection all light is cut off and the part appears black.

The three color process, therefore, is quite simple in theory, but its practical application to cinematography is a difficult problem. In the first place, silver bromide and the human eye do not agree in their sensitiveness to light of different colors. The photographic emulsion is very rapidly impressed by blue and violet, which appear dark to the eye, and even by the invisible ultra-violet, while bright red, orange and yellow produce very little effect upon ordinary films. These differences can be diminished, to some degree, by using orthochromatic emulsion, but even these retain an excess of sensitiveness for the more refrangible rays. Hence the reproduction of the natural colors in their proper relative intensity requires so long an exposure, through the green and orange filters, that instantaneous photography and cinematography are impracticable, except in special cases.

This is not the only difficulty, and none of the processes which have been proposed is free from defects. These processes fall into two groups, in which the analysis and synthesis of the natural colors are effected by successive images or by simultaneous images, respectively.

In the former case all of the partial negatives are made on a single strip of film, successively through violet, green, and orange-red filters. The camera shutter is usually a disk divided into three opaque sectors, which alternate with three transparent sectors, colored violet, green and orange-red, respectively. The mechanism is so constructed that the lens is covered by an opaque sector when the film is shifted, and by a transparent colored sector when the film is halted.

The same device is employed in the projecting apparatus, in which the film and the rotating disk are so adjusted that the pictures that correspond to the violet parts of the scene are projected through the violet sector, and similarly for the other two fundamental colors. The persistence of retinal impressions causes the three monochromatic pictures, if they succeed each other rapidly enough, to combine into one picture in natural colors. It is obvious that, in order to produce perfect fusion and to eliminate flickering, the pictures must be projected three times as rapidly as black-and-white pictures. It follows that the negatives must also be made three times as rapidly as the negatives for black-and-white pictures.

This increase of speed entails serious difficulties. We have seen that the lack of sensitiveness of the emulsion for green and red requires the exposure to be prolonged. If it is necessary, on the contrary, to shorten the exposure the process is restricted to exceedingly luminous objects photographed with a lens of great aperture and correspondingly small depth of field. In the second place, if the speed of the film is tripled, its length and cost are tripled also. (Fig. 1, No. 1.) Furthermore, the film is rapidly worn out by its violent displacement in the projecting apparatus.

The method of combination by simultaneous images does not require any increase in speed, for the three pictures can be placed side by side (Fig. 1, No. 2). The film is no longer than an ordinary film, but it is three times as wide and, consequently, it is as heavy and as costly as the film used in the successive method. The principal difficulty of the simultaneous method, however, is in the exact superposition of the images on the screen.

If the three series of photographs are made with three lenses, placed side by side, and each provided with a ray filter, the positives must be projected by three lenses, similarly placed and provided with ray

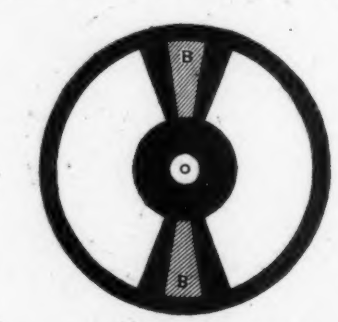


Fig. 4.—Improved kinemacolor shutter.

B, B, semi-transparent blue-violet sectors.

filters. But, as the distance between the screen and the projecting lantern is variable, the focusing of the three images is complicated by the effect of parallax. The three photographs are taken from different points of view and, therefore, like stereoscopic pictures, they are not exactly superposable.

If the scene contains only distant objects the three images can be superposed well enough by adjusting the distances between the projecting lenses. Pictures of near objects, the centers of which are accurately superposed, show at the edges colored fringes due to a lack of coincidence in the contours.

Inventors have tried to eliminate this defect by employing, either for making the pictures or for projection, a single lens, behind which the luminous beam is divided into three parts, two of which are deflected by mirrors

* Condensed from Ernest Coustet's article in *La Revue des Sciences Purés et appliquées*, and published in this journal.

and prisms to right and left, to form (or to reproduce) the lateral images, while the third part, not deflected, forms (or reproduces) the middle image. The lateral parts of the divided beam traverse a longer path than that of the middle part, and this difference of path must be compensated in order to bring all of the images into focus. The compensation can be effected by the interposition of lenses or of a number of plane-parallel glasses, but the lenses alter the relative dimensions of the images and the bundles of glass absorb much light and greatly increase the weight of the apparatus.

A great many three color processes have been patented, but few have given good results. The only one that has been exploited successfully in Europe is:

THE GAUMONT CHRONOCHROME PROCESS.

The Gaumont film is of the usual width and contains the three monochromatic pictures in regular recurrence, but each triplet is projected simultaneously. With pictures of the usual dimensions, 18 by 24 millimeters (¾ inch by 1 inch) it would be necessary to advance the film 54 millimeters, or more than 2 inches at each step. In order to lessen the danger of tearing and also to diminish the cost of the film, Gaumont reduces the height of the picture by one third, without altering the width, so that the dimensions are 12 by 24 millimeters (½ inch by 1 inch: Fig. 1, No. 4).

The pictures are projected by three superposed lenses (*A*, *B*, *C*, Fig. 2), the centers of which are separated by intervals equal to the height of a picture, but the lenses are segments of lenses of much greater diameter than this, so that they transmit abundant light.

The middle lense *B* is fixed; the other lenses *A* and *C* can be turned both vertically and horizontally. This rotation is required in order to superpose the images exactly on the screen. The regulation is a delicate operation and the operator is too far from the screen to observe the effect minutely. Therefore, he is aided by an observer placed near the screen who gives him needed warnings by telephone.

The three pictures are illuminated by a single electric arc. Three arcs would give more brilliant projections, but their fluctuations would injuriously affect the coloring. A very intense arc is employed in conjunction with a metallized screen, which, instead of diffusing the light in all directions, confines it chiefly to a small angular field. This method of projection is suitable only for small halls.

The reproduction of natural colors is perfect. This is strikingly shown in motion pictures of gorgeous tropical butterflies and flowers, mounted on rotating pedestals. The movement gives an impression of relief as complete as that produced by the stereoscope, and the illusion of reality is intensified by the play of color, especially in the wings of butterflies, the colors of which are due to interference and change with the direction of the illumination.

TWO-COLOR PROCESSES. KINEMACOLOR.

In the Urban-Smith kinemacolor process the component colors are reduced to two: red and green. The camera and the projecting lantern are similar to those used in the three color process with successive images, except that the rotating disk has only two transparent sectors, red and green, separated by two opaque sectors (Fig. 3). The film moves at the rate of 32 pictures per second, twice the usual speed, and its length (Fig. 1, No. 3) is twice that of a black-and-white film of the same subject.

The absence of the third fundamental color has been partly compensated by substituting for the opaque sectors of the rotating disk blue-violet sectors which are not sufficiently transparent to reveal the movement of the film that takes place when behind them (Fig. 4). By this device the predominant yellow tone of the screen picture is corrected. The blue color is spread uniformly over the picture, instead of being localized in the blue parts, but our eye is very tolerant and its synthesis of color is purely subjective. In the reproduction of natural colors, however, kinemacolor is far inferior to the Gaumont process.

THE AUTOCHROME PROCESS.

The three films and color screens of the three color process can be replaced by a single film composed of violet, green, and orange elements (Fig. 1, No. 5). If the colored elements are very small and uniformly distributed the film will appear colorless. If such a film is coated with silver bromide emulsion and exposed in a camera, the result will be a photograph in colors, in which a deposit of silver covers all of the little colored elements that do not correspond with the natural hues of the subject.

The production of color photographs of this sort has been the object of many researches. The most successful method yet invented is that of MM. A. and L. Lumière, whose autochrome plate is prepared with grains of starch, colored violet, green, and orange, thoroughly mixed and spread in a thin layer between the sensitive emulsion and its support.

This process furnishes beautiful lantern slides, but its application to motion pictures is attended with difficulties that have not yet been overcome. The colored starch grains, and the yellow glass required for correcting the tone of the picture, absorb so much light that, even with an exceedingly sensitive emulsion, the exposure must be at least 60 times longer than in monochrome photography, so that the production of motion pictures is impossible, except in special cases.

If this and other less formidable obstacles can be surmounted the autochrome process will furnish films lighter, less bulky and possibly cheaper than those of the three color process with successive images. It will not be necessary to reduce the height of the pictures or to employ a special lantern for projection.

Producing Steel Direct from the Ore

Many investigators have worked on methods of producing steel direct from the iron ore without resorting to the present preliminary process of reducing the ore in a blast furnace, and it is obvious that if a commercially practical process of this kind can be perfected a very great saving in time and expense will result, together with a considerable saving in ore. As a result of many experiments, it would appear that the electric furnace would give the best results as, for one thing, the uncertainties resulting from impurities introduced by fuel would be entirely avoided. In a recent issue of the *Journal* of the Iron and Steel Institute the results of experiments made by E. Humbert and A. Hethey are discussed. Experiments were made in a normal Héroult electric furnace of 6 tons' capacity, working with single-phase current. Three series of tests were made, namely: (1) Direct reduction of siliceous Swedish iron ore. (2) Direct reduction of Swedish and a siliceous Swedish iron ore, with 30 per cent of scrap mixed with the charge. (3) Direct reduction of Brazilian iron ore. It was found that good steel could be obtained without the carbon being above 0.4 per cent at any time. The steel forged very well and welded easily. The consumption of electrodes was at the rate of 32 kilogrammes per ton of steel. The wear of the lining was approximately the same as when melting scrap, but there was a good deal of ebullition owing to the liberation of large volumes of oxides of carbon. The outstanding quality of steel by this process is its toughness. The authors claim that the steel is more free from harmful gases, such as nitrogen, by this process; and that the direct method has the advantages of simplicity, ability to use refractory and richer ores, freedom from impurities, cheapness, and efficient control of the quality of the steel.

Circumventing Niagara Falls

A New Welland Canal Necessitated by Increasing Traffic

By Bernard Farrows

It was a spectacular feat to drive a canal across the Isthmus of Panama. The world has looked on in openmouthed astonishment as skillful engineers and toiling laborers have removed mountains, flooded valleys and dug enormous channels so that the commerce of the nations might flow from ocean to ocean.

In a sense it will be a scarcely less picturesque achievement to circumvent that great natural obstacle to the navigation of the Great Lakes of America, the Falls of Niagara, and by providing a ship canal around it, to enable the largest vessels now afloat in these waters to pass with facility from end to end of the long chain of lakes.

The latter task has been undertaken. Indeed, it is now well under way, and almost a year's progress has been made on the preliminary construction work. Awed doubtless by the superior accomplishments of the engineers at Panama, the men who are engaged in the enterprise at Niagara are saying very little about their undertaking, which is perhaps the reason why no one has heard very much as yet about it.

While the Welland Ship Canal, as the waterway is to be called, is to all intents and purposes an entirely new scheme, it will yet supersede a smaller canal which has been in existence many years. The circumventing of the Falls of Niagara is no novelty. It was attempted quite early in the history of lake navigation. As far back as 1829 two ships sailed through the partially completed channel from Lake Ontario to the upper reaches of the Niagara River, and four years later a thorough connection was established between Lakes Ontario and Erie from Port Dalhousie on the former to Port Colborne on the latter.

Since the thirties of last century, the Welland Canal has been twice rebuilt in order to accommodate the slowly enlarging types of vessels in use on the Great Lakes. The present canal, completed in 1880, was regarded at the time as the last word in canal construction. Its locks, twenty-six in number, and of dimensions 270 by 45 feet, were able to hold the largest ships then plying on the upper lakes, while the 14-foot channel was ample for the needs of the days.

But the amazing progress which has been made of late years in marine architecture has produced a type of lake freighter that far exceeds in length, tonnage, and draft the one-time generous measurements of the Welland Canal. The latter has been rendered entirely useless in the case of a large proportion of the shipping of the lakes, and once again the Niagara cataract's barrier has become an effective impediment. Compared with the traffic through the Soo canals, that through the Welland Canal is at present a mere bagatelle, which means that a very large percentage of the commerce of the upper lakes now terminates above the Falls.

As the bulk of the traffic through the canal at present is grain, and as few of the upper lake boats can pass, the Canadian government has recently built at Port Colborn, the Lake Erie entrance, an elevator of 2,000,000 bushels capacity for trans-shipping this grain into smaller vessels.

These facts established the need for a third enlargement of the Welland Canal and were considered by the government of Canada as of sufficient weight to warrant a reconstruction on a very much larger scale. The old route was examined with a view to sizing up its suitability for enlargement. It was promptly condemned, except for the southern section from Allanburg to Lake Erie. This meant a new location for the northern half of the canal and, after much prospecting, a route lying to the eastward of the old route was decided upon. Plans were promptly prepared for the construction of the canal and about a year ago work was started, at an estimated cost of $50,000,000.

As comparisons often present a more illuminating idea of a subject than plain statements of fact, the importance of the new project may perhaps be better gaged by comparing it with the Panama Canal. The Panama Canal has a length of fifty miles from ocean to ocean; the Welland measures twenty-five miles from lake to lake. The minimum width of the bottom of the channel in the case of the Panama Canal is 300 feet; in that of the Welland Canal it is 200 feet. The minimum depth of water throughout the Panama Canal is 41 feet; in the Welland Canal it is 25 feet, though all permanent structures are to be made so that at any time the channel can be dredged to a depth of 30 feet.

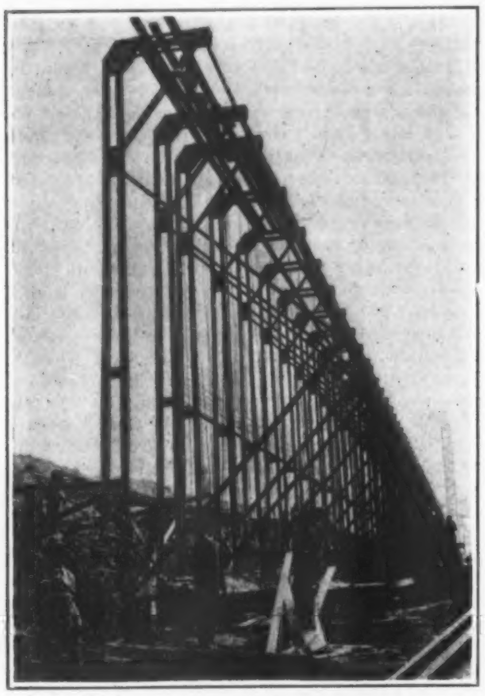
The Panama Canal consists of three sections, viz., the Gatun Lake, formed by the damming of the Chagres River, and the channels leading to it from the Atlantic and Pacific, respectively. The mean level of the lake is 85 feet above sea level and ships are raised to its level by means of six locks, three at either end of the lake. The locks measure 1,000 by 110 feet, with a minimum depth of water over the sills of 41⅓ feet, when the lake is at its normal level. Each has a lift of 28⅓ feet.

The Welland Canal, on the other hand, cannot be divided into such well-defined sections. Its course is entirely upward from Lake Ontario to Lake Erie, or, in other words, it has no summit level equivalent to Gatun Lake whence ships must be locked down again. The rise is contained almost entirely within a few miles of Lake Ontario and amounts to 325 feet, the difference in level of the two lakes. This is overcome by means of seven locks, of which Nos. 4, 5, and 6 are double and arranged in flight. The uniform size of the locks is 800 by 80 feet, with 30 feet of water over the miter sills at extreme low stages in the lakes.

There is a further interesting comparison which may be instituted. The larger of the lock gates in the case of the Panama Canal each measure 65 feet in width by 82 feet in height and weigh 730 tons. These gates are of the double-leaf variety, hung on either side of the end of the lock and mitering in the center when closed. In the case of the lock gates for the Welland Canal, a novelty is to be introduced. The latter will not be double-leaf gates, but will be all in one piece and will swing right across the ends of the locks into mortises,

They will measure 83 feet in height and 88 feet in width and will weigh 1,100 tons. It is believed by the designer that the new type of gate will be less liable to accident and will prove superior in many respects to the old-style double-leaf gate. The Welland Canal gates will not stand squarely across the channel, but will slant into the opposite wall, the length of the gate being 3 feet more than the width of the canal. The submerged portion of the gate will serve as a floating chamber and will relieve the pivot upon which the gate is swung of much of its weight, although the pin is designed to carry the weight of the gate plus its weight filled with water.

Another point of interest in connection with the Welland Canal locks relates to the source of supply of water for filling them. Hitherto it has been customary to draw the water from the channel above each lock and, when the dimensions were small, this was a satisfactory enough method. But with the huge basins of the new locks to fill each time a ship went through and with the rapid system of operation invented, a strong current would be set up which would interfere with navigation and tend to wear away the banks. Accordingly, above or beside each lock on the new ship canal, provision is being made for large reservoirs of water, from which the supply for filling is to be drawn. The water will consequently enter the locks through the side walls and not through the upper ends, completely obviating the disadvantages referred to.



Steel core framework of retaining wall at the Lake Ontario entrance of the new Welland canal.

The foregoing facts and figures will serve to show that the Welland Ship Canal, while by no means the gigantic project that the Panama Canal was, is still sufficiently near it both in size and in many engineering features to be classed as a notable undertaking. It is true that there are to be found at Niagara a few of the serious obstacles to progress which made the work of building the Panama Canal so long-drawn-out and difficult. Conditions for carrying out the work are much better in the northern hemisphere than in the tropics. The contractors are near their base of supplies; labor is plentiful; the climate is healthy. Above all, there will be no discouraging Culebra Cut to try the patience of the engineers. The going will be comparatively easy and for many miles will consist simply of widening and deepening the existing channel of the old canal. The total excavation, as estimated by the chief engineer, will only amount to 46,000,000 cubic yards, as compared with 220,000,000 cubic yards at Panama.

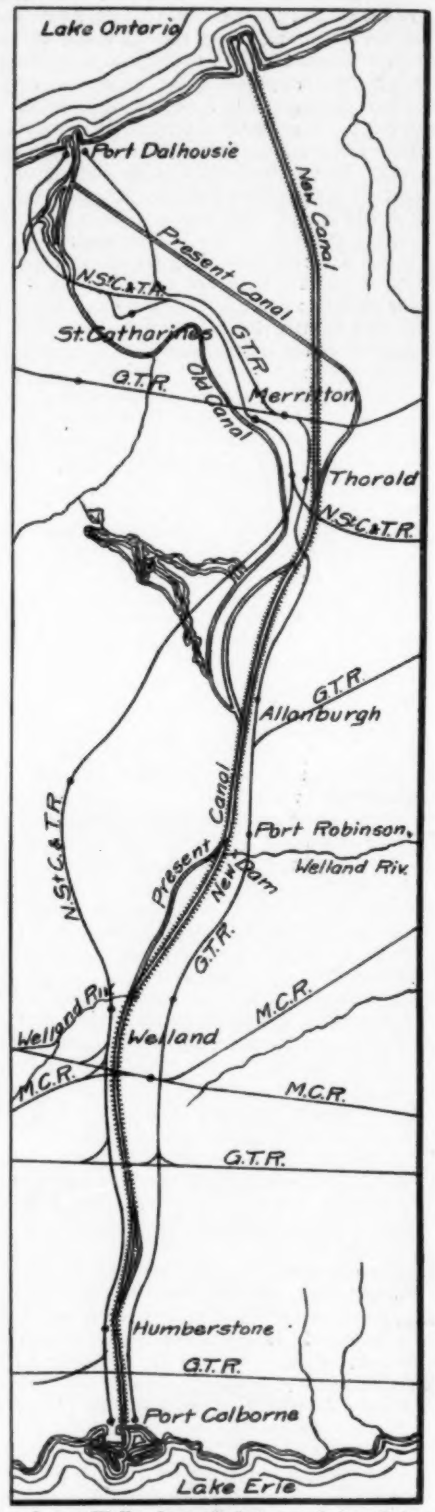
A satisfactory beginning has been made, as already indicated, and from Lake Ontario to the summit of the Niagara escarpment, good progress is to be noted in the work of excavation. The usual methods are in vogue. From the base of the escarpment to the shore of the lake the contractors have built a well-equipped standard-gage double-track railway, along which the material gouged out by the steam shovels is conveyed. For the present it is being used in building the piers that will form the capacious harbor of Port Weller. The lake shore at this point was unbroken and without any natural facilities for forming a harbor. It became necessary therefore to build an artificial shelter for ships entering or leaving the canal, and, accordingly, two piers, 500 feet in width and a mile and half long, are being thrown out into the lake.

From the inner end of the harbor to the entrance of Lock No. 1, which will be located quite near the shore, retaining walls of unique construction are being built. These consist of triangular frameworks of steel, set in solid concrete and reinforced with numberless iron rods. The frames are encased in cement forming a long series of pockets, which in turn are filled in with sand and gravel. It has been demonstrated that this style of wall is quite as effective as solid cement and of much more economical construction.

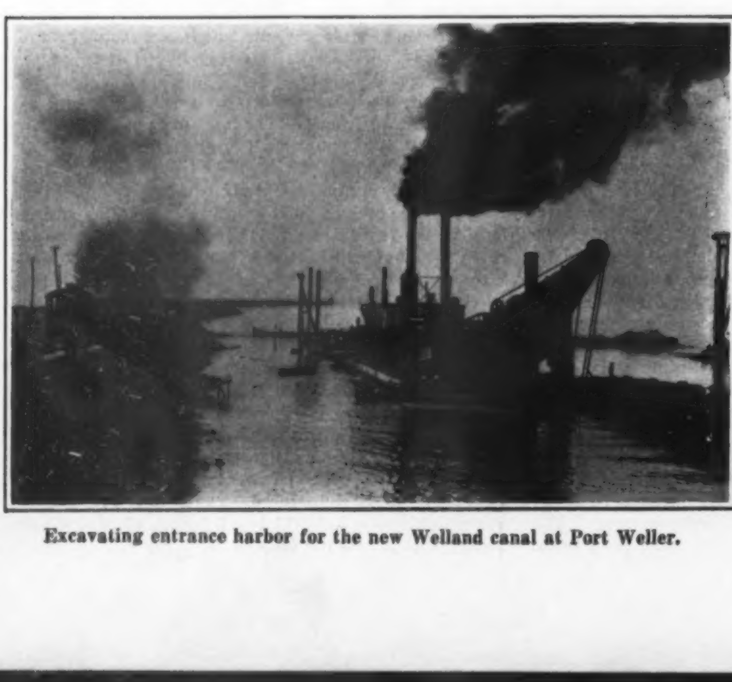
Naturally, the building of the ship canal is working great changes in the countryside. The section from the lake to the foot of the escarpment crosses what is known as the Garden of Ontario, a district famous for its production of peaches, grapes, and all kinds of small fruits. In its course the canal devastates many fine orchards and has caused the diversion of roads and a general cutting up of the landscape. At least two railways have had to be lifted to new rights of ways to make room for it and one small town has been cut in two by its deep excavations.

As originally estimated, 1918 was to have seen the completion of the work. Owing, however, to conditions imposed by the war which have compelled the Canadian government to cut down their expenditure on the canal, the time of construction will be spread over a longer period, and it may be 1920 or even later before big ships can use the new route from the upper to the lower lakes.

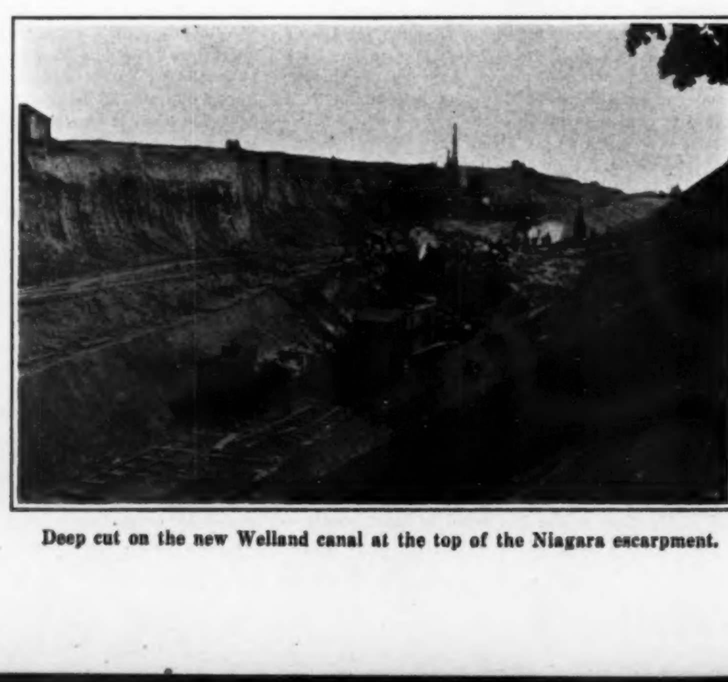
Meantime it is possible to consider the significance of the project and to estimate what its completion will mean to lake navigation. Eight hundred-foot locks and a 25-foot channel mean that not only can lake vessels of the largest tonnage use the canal, but that many ocean liners will be able to pass through to upper lake ports. While much of the traffic of the lakes will continue to terminate at or above Buffalo, there is no doubt that a considerably larger proportion of it than heretofore will descend to Lake Ontario through the new canal. Assuredly, conditions will be very much changed when the Niagara cataract is once more effectively circumvented. The bulk of the freight traffic to be handled on the new waterway will be grain, though there will be enormous quantities of coal and other bulk freight destined for upper lake ports. According to the liberal Canadian regulations, the canal will be free to all vessels using it. It will be of great benefit to the United States as well as to the Dominion of Canada.



Old and new Welland canals between Lakes Erie and Ontario.



Excavating entrance harbor for the new Welland canal at Port Weller.



Deep cut on the new Welland canal at the top of the Niagara escarpment.

Assembling shops for large work.

The central shops of the Cockerill Works.

The Cockerill Iron Works

One of the Famous Manufactories of Belgium

By Our Paris Correspondent

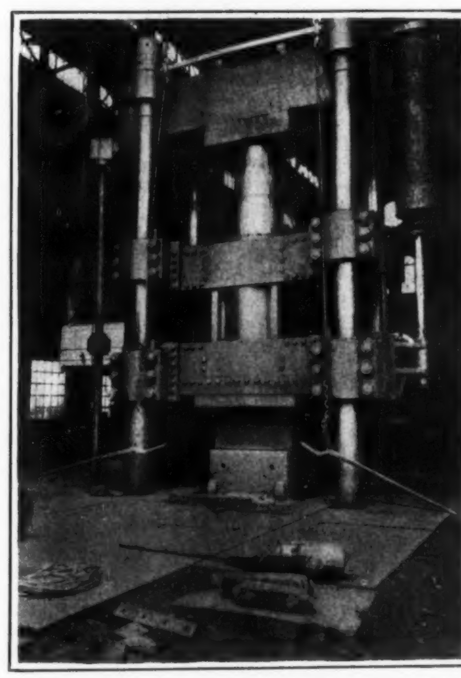
THE forts of Liège, Antwerp, and Namur which figured so prominently in the recent war events in Belgium had their heavy armor plating constructed at the Cockerill Iron Works, located at Seraing, near Brussels. Cannon and all kinds of heavy war material were also a specialty of this great establishment, and, in fact, the Cockerill plant ranks among the leading iron works in Europe. Since the occupation of Brussels by the Germans, we hear that the works have ceased to run for lack of workmen. The leading position which the great works occupied in the manufacture of war material will make a description of the various parts of the plant a timely one just at present, and the following account is taken from data furnished by the company at a previous period. The Cockerill plant extends over a large area upon the Meuse River and the tracks of the North Railroad lead through it.

Firing tests on a piece of 8-inch armor plate for cupola forts.

John Cockerill, the son of an English emigrant, became noted at an early age for his mechanical ability, and this contributed in a large part to the progress of the spinning and weaving industry at Liège and Verviers. In 1817 he received from the King of Holland the chateau of Seraing and grounds in order to set up construction works, and the new shops grew rapidly. A few years later the machines built here could rival the best English machines, the only builders of importance at that time. English industries were, in fact, largely introduced on the Continent through the Seraing works throughout the century. A blast furnace operating with coke appeared here in 1824 and worked a revolution in cast iron processes on the Continent; and again, by the use of steam engines for metallurgical work, Cockerill was a pioneer in iron working as well. Considerable credit for steam transport development is due to him and his corps of engineers, and some of the first and most remarkable marine engines were built here in the early stages. It is worthy of note that Ericsson, whose name became so famous, passed the period of 1825-1827 at Seraing, and was engaged in designs of a boat which had high-pressure boilers with inside grate using forced draught, also engines with surface condensation, all of which ideas were, however, too advanced to succeed at that date.

A few years later saw the commencement of railroad building in Belgium, and the enterprise of the Cockerill works was shown by the construction, in 1835, of the first locomotive and the rolling of the first rails to appear on the Continent. From that time on locomotive building made rapid progress at the works, and all the newest European ideas entered into the designs. After that came the industry of drainage pumping engines for mines and the like, and as early as 1847 the celebrated pumping engines of Bleyberg were the most powerful of the Cornwall type used on the Continent. The use of compressed air for power work at great distance, especially for mines and large tunnels, is one of the problems that received its industrial solution at the works, where the engineer Germain Sommeiller in his bold and unprecedented work of tunneling Mount Cenis, found the active and ingenious collaborators by whose aid he built the numerous apparatus needed for this vast enterprise.

It was reserved for the Cockerill works to introduce on the Continent what may be termed the leading invention in modern metallurgy, namely, the manufacture of steel by the Bessemer process, and the first converters



Big forge press for shaping armor plates at the Cockerill Works.

started work in 1863. They were also pioneers in the practical utilization of blast furnace gases, the first idea being due to their engineers Bailly and F. Kraft. In 1895 there was set up in the shops the first trial machine of 8 horse-power of Delamarre type, this being the first motor to operate on blast furnace gas, and the industry soon took such a rise that at present the firm

One of the big shops at the Cockerill Works.

Where special tools, gages, and templates are made.

and their licensees have now built gas engines to the extent of 200,000 horse-power. Passing over the construction of the Diesel engine, which has become a prominent feature, the matter of military construction may be mentioned, in which the works took a leading part. But little of this kind of work was done during the early days of the works, and it was only in 1888 that the Belgian government decided to have all of its war material built in their own country. Since then the Cockerill establishment has taken an important place in the production of military supplies, and it has been so successful as to attract considerable foreign trade. Among the military work which was carried out within recent years was the construction of the cupolas for the forts of Namur and Liège, the armament of the new forts around Antwerp, and the renewal of the field artillery. At a recent date the Belgian government made a long series of trials on fortress material, and as a result it made the choice of the Cockerill steel for the armor plating of cupolas in general. Besides, it adopted the system of cupolas which the company proposed after the designs of engineer E. Ternström. The new system for the defense of Antwerp was entirely based on the application of these interesting constructions.

The area now covered by the works is 375 acres, of which 40 acres are occupied by various buildings. The firm is capitalized at the present time at $2,500,000, and is a stock company. Since the foundation of the works in 1842 to June 30th, 1909, no less than $20,000,000 have been spent for enlarging the works. In this way the raw material resources, coal, ores, etc., were increased and the general development of the works assured. Workmen now employed number about 10,000, and all possible means are taken to secure the comfort and advancement of the men by means of various institutions, such as schools, medical service, and aid given to co-operative enterprises.

One of the largest buildings on the grounds is occupied by the central machine shops, and the great hall measures about 400 feet long by 150 feet wide. One part of the shop is devoted to assembling benches, and the workmen are organized in brigades so as to become skilled in assembling of each type of machine. Two 2-ton electric traveling cranes run in the shop. A special shop contains the tools for work which requires great precision, and here are made the gages and templates which the shops require and all kinds of standard work of this class.

The locomotive works occupy an area of 4,000 square yards and have four electric traveling cranes, capable of lifting loads up to 45 tons, which allows of the ready handling of heavy pieces. Locomotives are taken in and out of the shop on an electric platform of 80-ton load. Here are to be seen types of a light locomotive with vertical boiler for service in shops or on special tracks, and this is one of the firm's specialties. As to large locomotives, most of the types in use on the Belgian state railroads were designed and built here; and among foreign countries furnished France, Italy, Spain, Portugal, and Russia are included. A second shop of 2,000 square yards area is used for light boiler work, sheathing, copper tubes, or mounting of tenders. Locomotives types are in widest variety and go from the lightest up to heaviest kinds used for international traffic.

A special shop of large size is used for assembling of the heaviest types of work, such as large steam engines, blowing machines for blast furnace, pumping machines, rolling mills, or large gas engines. The hall has an area of about 6,000 square yards and contains three divisions, the middle one being about 70 feet high, for assembling of large apparatus, while the side halls have a number of large machine tools. Cranes of powerful build are used here, comprising two electric cranes which can lift 45 tons and run across the main shop at a height of 50 feet. On the same rails is a smaller 5-ton crane. Other travelling cranes of from 5 to 25 tons capacity are installed in the side aisles of the shops, and facilitate the handling of heavy forging and castings, and are convenient for placing such pieces on the machine tools.

The great hall for forging machines was entirely rebuilt in 1889, and has 330 feet length and 65 feet width. One side is occupied by a line of sixteen reheating furnaces. Five electric cranes handle the pieces from furnace to hammer or forge-press, these cranes ranging from 15 to 70-ton type. Large hydraulic forge-presses are to be seen here, such as the 2,000-ton type which is illustrated. Rolling-mill rolls up to 20-ton size can be forged. Production of armor plating is a leading feature of the works. Contrary to the usual practice, the caps for foot cupolas are completely forged in the hydraulic press. Ingots of square section are pressed into plates, and the caps are cut out of these plates in the form of disks; then after reheating, the disks are pressed into convex shape between molds, after which they are carefully tempered and hardened. One illustration represents firing tests made upon a piece of 8-inch armor plate for cupola, and it first took five projectiles fired at a muzzle velocity of 1,500 feet per second. On a second round, it stood eight other projectiles shot at velocities up to 1,760 feet per second.

The artillery works and the various shops therewith connected turn out a great variety of ordnance. Among these we note cannon of fortress and marine types, field guns, rapid-firing cannon, mortars or howitzers of rapid-firing types, special varieties for colonies and others manufactured from nickel steel, also gun carriages and the like. Projectiles are in great variety, and other material of this class.

Other parts of this great plant must be passed over briefly, but mention should be made of the six blast furnaces located on the grounds and the large steel works with five Bessemer converters for 1,000 tons of steel ingots daily, together with three Siemens-Martin furnaces of 15-ton charge which, combined, will give great 45-ton ingots. Much of the coal used comes from mines which are situated on the premises, and ores are brought from Lorraine, Luxembourg, and other places.

Marketing Our Food Products

One of the most important investigations undertaken by the Department of Agriculture, as outlined by the Secretary in his annual report, is in relation to the marketing of food products; and that an improved system is badly needed may be illustrated by the following statement quoted from the report:

"Michigan dressed veal calves expressed to South Water Street commission houses at Chicago have been returned to the identical shipping points from which they came to fill orders from local retail markets."

Similar conditions largely prevail in regard to almost every other product of the farm, and it is evident that some improved system of distribution that will stimulate local markets and eliminate the expense of many intermediate handlings and heavy transportation charges must be developed to counteract the rapidly increasing cost of food, for all of these expenses must be borne by the consumer.

This subject, however, did not originate with the Department, for it is a movement that has sprung up in various parts of the country in response to the realization of the necessity for better methods of marketing; but to be fully effective a system adapted to the whole country should be devised, and this is the work now being undertaken. As a preliminary, information as to what has already been done is being collected, and this will form a most valuable basis upon which to formulate future plans.

"A record of more than 8,500 marketing associations, of about 2,700 co-operative and farmers' elevators, of 2,500 co-operative and farmers' creameries, and more than 1,000 co-operative fruit and produce associations has been secured. While the survey is not complete, it is reported that over a billion dollars' worth of agricultural products are annually marketed by co-operative and farmers' marketing associations.

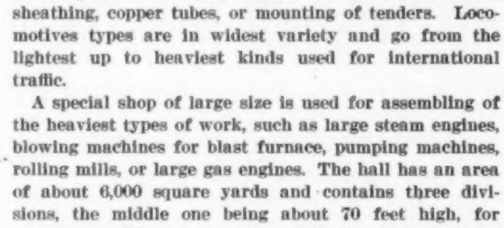
"The conclusion seems justified that in communities where farmers' associations are properly constituted and operated better results are obtained than under a system of individual handling. Advantages present themselves in the standardizing and packing of products and in the discovery of the best daily market. Much information has been secured as to the laws of the various States under which such organizations may be created. The effort is being made to determine the principles on which the enterprises that have succeeded have operated and those upon which the enterprises which have failed have proceeded. Likewise inquries have been set on foot concerning market centers, the market surplus, the rate of movement, the outlets for commodities, the prices of specific products by definite trade areas, and the possibilities of increasing distribution in an economical way."

Even if these investigations do not lead to any governmental action, the information secured will be invaluable in enabling different sections of the country or individual communities to formulate methods adapted to their requirements.

Detecting Polarity of Electric Circuits

In these days when there is such a multitude of electrical appliances on the market, for every imaginable purpose, it is often desirable to ascertain the polarity of the circuit on which some device is to be used. A sure and simple method of determining this is described by F. P. Ampudia in a recent issue of *Power*.

The sketch shows a simple means of detecting polarity in a direct-current circuit. It consists of a wooden board upon which is mounted a 16 candle-power lamp



Apparatus for detecting polarity in direct-current circuit.

and socket, in circuit with two terminals C and C' and two pieces of fusible wire P and P' which project into a glass containing water with 8 or 10 drops of sulphuric acid.

When the terminal posts have been connected to the circuit the lamp will light and bubbles will appear in the glass. Within a short time, one of the leads in the water will become brown and the other a bright gray. The former will denote the positive and the latter the negative wire.

Good Roads and the Government

In his annual report, the Secretary of Agriculture takes a very practical position on the question of good roads and the relation of the Government thereto.

"Good roads are equally intimately related both to the production and distribution of farm products. They are prerequisite not only to economical production and distribution, but also to the promotion of the broader life of the communities. The great need, obviously, is for roads which shall get products from the farm to the nearest railway station, enable the farmer to haul when he cannot sow and reap, and to haul at a lower rate, to transport his children to consolidated schools, and to enjoy comfortably his social enterprises. It is estimated that is costs 23 cents under existing conditions to haul a ton a mile on the average country road, and that this could be reduced by one half if the roads were improved. The problem is partly, of course, one of funds, but even more largely one of methods, of instrumentalities, and of administration. The Nation to-day is spending annually the equivalent of the huge sum of $200,000,000 for roads, an enormous increase in the last decade. Much of this is directed by local supervisors, and it is estimated by experts that of the amount so directed from 30 to 40 per cent is, relatively speaking, wasted or misdirected."

That this should be the case is not in the least surprising when we learn that less than half the States have expert state highway commissioners, and very few of them have any sort of expert local machinery; and this strongly suggests that present methods of distributing the Nation's money on the basis of the political results to be obtained should be revised. In his suggestions for future procedure, the report suggests that if direct Federal aid is to be extended it should be done only under such conditions as will guarantee a dollar's results for every dollar of expenditure, and partly in view of this, it is suggested that "legislation should provide for co-operation between the Federal Government and the States, and that the State, through an expert highway commission, should be the lowest unit with which the Federal machinery should deal. If the law recognizes only a central highway commission, it will strengthen the hands of those that now exist and secure the creation of such bodies in the twenty-six States that do not now have them. The mere creation of such bodies in every State would be a marked gain."

In formulating road schemes, those interested usually find it convenient to omit any reference to the equally important feature of maintenance, but in regard to this the Secretary wisely states that the expenditures of Government money should be limited strictly to construction projects and not used for maintenance, which, he truly says, would involve the Government in a very unsafe and uncertain course.

Training Elephants in the Belgian Congo

The authorities in the Belgian Congo have been making some interesting experiments in raising and training the native African elephants for domestic uses, and results of his work were given by Capt. Laplume, the director of the elephant training station, at the International Congress of Tropical Agriculture. A training station was erected at Api where elephants are particularly numerous. Capt. Laplume captured his first elephants in 1900, and in 1903 he had caught fifteen of these animals. He has now thirty-four. As the young captives became tamer and older, he started training them for agricultural work (carrying, cart-traction, plowing). The station now possesses sixteen elephants perfectly trained to this work The training of the young elephants is not difficult, and some of the oldest animals are now put to regular work.

The Psychanalytic Movement—I*

Its Services in the Prevention of Insanity

By James J. Putnam, M.D.

I UNDERSTAND that the problem before us for discussion is, How can we best help people to preserve their mental health? and that my part in it is to answer the particular question, What contribution can psychanalysis make toward this end?

It is, however, germane to say that inasmuch as psychanalysis is best definable, from the therapeutic point of view, as an educational method of high value, and since, under all circumstances, it exerts its usefulness largely through helping the patient to become a more thoughtful, more rational, and more mature person, the aims of prevention and the aims of treatment are to a great extent the same.

It is my confident belief that the contribution of the psychanalytic movement to prevention is to become an important one, but that it will make itself felt not so much directly, through the treatment of individual patients, as indirectly and gradually through the stimulus which these searching studies into the nature and history of human motives must exert on parents and educators, in proportion as the principles discovered or emphasized by them become an integral part of psychologic doctrine.

To assert that it is possible to prevent or cure a psychosis by mental influence is equivalent to asserting the psychogenic origin of these diseases. To maintain this is not to deny that special toxic influences, general disorders of metabolism, or abnormalities of cerebral structure or development may play an important part as predisposing causes, or even that the influence which these causes exert in one or another case may have been the controlling influence, *sine qua non*.

It is, however, certain that even where this is so, the mechanism of the psychosis, as a mental phenomenon and as the sign of the occurrence of a mental process having a more or less clearly definable aim and meaning, ought to be specifically studied, and that in order to do this thoroughly the physician should have made himself aware of the patient's inner life, both as an individual and as a member and representative of a social group or social groups.

The psychoses and psychoneuroses are not to be regarded (psychologically) as mere misfortunes or mere accidents, but as phenomena that represent definite, instinctive attempts at readjustment and the securing of some workable equilibrium, on the part of persons whose actual adaptation to their environmental conditions had proved unsatisfactory in the face of this or that special strain, and whose powers of readjustment had shown themselves inadequate to the task of restoring the disturbed balance in any better fashion. This view is in harmony with that of Meyer, Hoch, Bleuler, and others who have stood for a partially psychogenic origin of the psychoses, and have recognized that the constitutional and temperamental make-up of each patient's personality is partially responsible for his illness, or, as I should say, for the method which he instinctively adopts to reassert himself. The psychoses form, in short, one more illustration of the general principle that illness may be classified as the manifestation of efforts toward a certain sort of health.

It seems at first sight almost impossible to get away from the patient's conscious point of view, and to deplore with him and his friends, as if for a misfortune without mitigation, the signs of an oncoming mania or depression or paranoia or dementia praecox. But if, through the aid of knowledge and insight, one can succeed in placing oneself in the depths of the patient's mind, at the center of his vain struggles to make the conditions around him square with his desires, even though these be immature and narrow, it becomes possible to see that his illness may have furnished him a real way out of his perplexity, even if not the one that we, looking on, or he, if possessed of full conscious insight, might have wished to see adopted. The justice of this conception becomes clearer if one scrutinizes, to begin with, the psychologic significance of one's own fits of temporary depression, of the "blues." Whatever else the "blues" accomplish, they certainly afford us the chance to bury ourselves in an ocean of self-engrossment, self-pity, or self-commendation in which we may become for the time being almost as thoroughly immersed as a dementia praecox patient in his delusions. The difference lies in the power of emergence and its special causes.

It occasionally happens that a patient with obsessive fears is intelligent enough (after a certain amount of treatment) and frank enough to see and say that in some respects he feels better satisfied with the prospects offered by his dissociation than by those offered by health; then, namely, when to be well means the facing of situations and renunciations that he is unwilling to contemplate. The only alternative recourse seems to be suicide. As a rule, of course, the logic of the process is concealed from his conscious view. Such persons are somewhat like children, who learn to create, in fancy, a separate realm of feeling and fancy, to which they may retreat[1] for the private enjoyment of emotions in which the other elements of their nature do not permit them openly to indulge. In this realm of fancy the child may become for the time a king, or a being to whom all sorts of excesses of imagination are permissible. If, however, he stays in this realm too long, the return into a life of relative reality[2] and social responsibility may be attended with difficulty. The justification of this comparison only becomes clear when (as sometimes in dementia praecox or paranoia) it is possible to get at the patient's delusions from their deeper and, to him, better side.

What such a child does for a brief space, when he withdraws into this delightful world of fancy, peopled, it may be, by beings from some other sphere,[3] the paraphrenic (i. e., "dissociated" or schizophrenic) patient may—in the terms of this important theory—be said permanently to do. And, *mutatis mutandis*, similar statements may be made for manic-depressive and for paranoid patients. Such persons may, namely, become in different degrees and ways, so preoccupied with the details of their "autistic" life, even when, to the untrained eye, this does not appear to be the case; they may get so immersed in their fantasies and daydreams that they lose touch, to a greater or less extent, with the life of relative reality.

We are too apt to define each other's tendencies in terms of misfortune, weakness, deficiency, and lack. This procedure is misleading. There is really nothing negative in nature. If a plot of ground does not grow grass, it runs to weeds, but the weeds are as positive in their nature as the grass and often more resistive to destruction.

Life may often be said to consist in the gradual (at times apparently sudden) abandonment of equilibriums which had sufficed well enough up to a certain point, in favor of new and more insistent equilibriums that loom up as representing, as the case may be, a more advanced (sublimated) or a more regressive (infantile) but seemingly more stable stage of evolution or of evolutionary tendency.

It is in the terms of this process that the history of the psychoses should be written.

But I pass, now, from the consideration of the mechanism of the psychoses and the needs of the distinctly neurotic child to the subject of preventive education in the stricter sense, and I attempt again to answer the question, What contribution has psychanalysis to offer.

As I have already indicated, this contribution will perhaps always be mainly an indirect one. I propose nothing so insensate as that parents, or even teachers, should practice psychanalysis; but I maintain that this branch of medicine has something to offer to parents, more to teachers, and a good deal to the family physician. All these classes of persons need to have their own points of view reformed before they attempt to form the character of the child. They need a wider comprehension than that which has been current hitherto, as to what the psychologic nature of the child is, and what his purposes and his dangers are, as expressed in terms of his conflicts, his concealed and repressed thoughts, feelings and desires, and his so often misused imagination; and they need to have this knowledge on the basis of a thorough acquaintance with the psychology of human nature in general, as gained through clinical research.

I presume it will hardly be disputed that the kind of person who most completely fulfils his destiny is he who looks on himself not only as a private and independent individual, but also as at once a member and a representative of the community in which he lives, then of a widening series of communities, and eventually of an ideal and all-comprehensive community. This proposition was long ago made the basis of the educational system of Froebel[4] which should be accepted as offering the best prophylactic method at our command, applicable to all children, though its influence might easily go for nothing unless reinforced by that of the child's environment and home.

But although definitions of this sort are generally accepted as indicating theoretically a suitable scheme of human opportunity and obligation, yet the observation of human conduct leads to the conclusion that the sentiments corresponding to them do not exert the thoroughgoing influence that one might look for. Obviously, these sentiments are but imperfectly accepted by some portion of the minds of most men. The very prevalence of the psychoneurotic illnesses and of the corresponding defects of character and temperament from which all men suffer in some measure indicates that this is true. For many of these forms of illness, as well as many of the defects of character, are largely based on the self-assertion of the individual in the narrower sense, with his demand for personal "rights," and his (largely infantile, and thus selfish) longings and cravings, as against the assertion of his broader, his ideal self, recognizant rather of obligations to the community and of capabilities for usefulness than of rights.

It may be urged that psychanalysis does not take the cultivation of social ideals as an end for which it should directly strive. Technically, this is true. But psychanalysts know well the evils that attend the over-assertion of personal desires, cultivated too exclusively in and for themselves, and the importance of the opposite course follows by inference. The primary task of the psychanalyst is to remove handicaps to progress, but only in so far as these give rise to painful conflicts in the mind. They can, however, see and should indorse the schemes of education by which these handicaps are best avoided.

We ought to work for the maintenance of those educational systems and principles that help children first to feel and then to see that every man is most truly himself as an independent agent when he feels himself bound to merge his private interests in the interests of persons and causes outside of himself. But this tendency should go, in word and conduct, no farther than it is expressive of a genuine sentiment.

Social sentiments of this better sort and the conduct based on them should not be regarded as implying standards seldom to be reached, but rather standards to which many persons might measurably attain. Children, especially, are natural idealists and respond to appeals which adults often dismiss as idle.

(*To be continued.*)

* Abstract of a paper read before the Section on Nervous and Mental Diseases at the Sixty-fifth Annual Session of the American Medical Association, Atlantic City, N. J.

[1] Compare Bleuler's Das Autistische Denken. Jahrb. für Psycho-analytische und Pathologische Forschungen, iv, 1.

[2] I say "relative reality," because even the most conventional and usual sort of life gets its form and color from the imagination of each individual. Each person's world is, in part, his personal world alone.

[3] I have a patient at present in mind, of good intelligence, but small in stature and timid in temperament, who suffers both from depression and from compensatory ideas of courage. All his life long he has gained great satisfaction from day-dreams of power and prominence. Even at the present time, when he is about 22 years old, he occasionally imagines himself to be a supernatural being, wandering through space in the skies or "talking with God," and dreams of driving a four-horse sleigh or piloting a swift boat into that unknown world from which, in reality, he shrinks.

[4] Froebel: The Education of Man; see also Report on the Kindergarten by Susan E. Blow and others.

Testing High Tension Insulators for Leaks

AN ingenious method of detecting leaks in the insulators of a high tension electric line has been reported as follows: A specially constructed set of 2,000-ohm wireless telephone receivers is connected on one side by a sharp metal spike driven into the pole carrying the line, and the other side is grounded several feet away by a metal pin in the earth. If the insulators are sound a clear hum is heard of the same tone as in a telephone line; but if one of the insulators is leaking a scratching noise is also heard in the instrument. The particular insulator at fault may then be easily detected by the usual tests between the insulator pins and the cross-arms. This device is saving a great amount of time and labor, as a defective insulator can be detected from the ground, without climbing each pole. It may be said that there is comparatively little trouble from defective insulators now, as great improvement has been made in their quality, and they are all now subject to test of 120,000 volts for five minutes which quickly eliminates defective work.

Why Rivers Overflow

How Floods May Be Prevented

By Arthur E. Morgan

Miami River at low stage, about twelve miles below Dayton, Ohio.

Showing erosion of banks by the 1913 flood, and in the distance the piers of a highway bridge which was swept away by the flood. The river here is about 5 feet deep at low water and about 400 feet wide between the natural banks, which are about 7 feet above low water. In the 1913 flood the water rose 22 feet above low water, submerging the natural banks 15 feet and spreading over the valley to a width of one half mile. The channel capacity is about 10 per cent of the flood flow of 1913.

In making engineers and the public acquainted with plans for flood prevention it would seem unnecessary to begin by an explanation of "What is a river?" Yet confusion of ideas and misunderstanding on this point is a most prolific source of difficulty, not only with the public, but with many engineers.

A commonly held impression concerning the origin and functions of rivers might be expressed somewhat as follows:

"As a part of the work of creation it was necessary to design and to create a system of channels for the purpose of carrying to the ocean the surplus water falling upon the land. This being the object for and the manner in which rivers were created, they must necessarily serve the purpose, unless they have been abused in some way. If floods occur and do great damage, it must be because men have cut down the forest or have obstructed the channels, or have occupied a part of the channels which rightfully belong to the rivers."

This attitude was expressed by a U. S. Government engineer who addressed a gathering of people in Ohio after the floods of March, 1913. He is quoted as saying that the flood occurred, not in the rivers as God made them, but in rivers obstructed by *débris*, by buildings in the channel, and by bridge piers.

As a matter of fact, a river is not made to order. It is nothing more or less than the accidental path made by water in following the line of least resistance. There is no necessary relation between channel capacity and flood discharge, and whether the path is large enough to carry flood flows depends entirely upon the natural conditions which have existed while that path was being made. Within the United States one may find rivers in all stages of development, from the river which has entirely lost its channel and is slowly digging a path for itself through the flat coastal plain, to the one which has dug a larger channel than it can ever fill. For instance, the Hudson River from Troy to its mouth, even in times of extreme flood, is no more than the small thread of a stream flowing along the bottom of a deep gorge which the river has cut out for itself during past ages. A still more extreme case is the middle section of the Colorado River, where it flows as a tiny thread at the bottom of a gorge a mile deep. The word "cañon" is used to describe a river channel in which this deepening of the bed has been carried to an extreme.

Fig. 6.—During overflow on the Mississippi River.

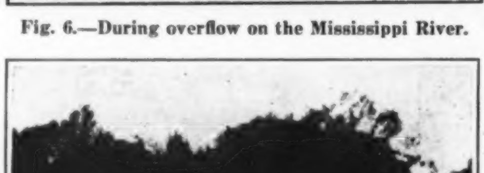


Fig. 7.—Showing depth of overflow of water forty miles back from the river channel—Mississippi River.

On the other hand, many rivers fail entirely to dig channels sufficient for the flood flow. The natural and unimproved channel of the Miami River in Ohio has a capacity of about 10 per cent of the greatest discharge, such as occurred last year. The Black River, where it leaves the Ozark Mountains in Missouri, has a drainage area of about 1,450 square miles, and a probable maximum flood discharge of about 140,000 cubic feet per second. The capacity of the river channel through the plains after it leaves the hills is about 4,000 cubic feet per second, or about 3 per cent of the possible maximum flood. The St. Francis River, where it leaves the mountains in Missouri, has a drainage area of about 1,600 square miles, and a maximum flood discharge probably in excess of 150,000 cubic feet per second. It has a channel capacity through the flat lands of a few hundred to about 10,000 cubic feet per second, or from less than 1 per cent to about 5 per cent of the extreme flow. The Coldwater River, in northern Mississippi, has a drainage area of more than 1,000 square miles of hill land in a region of heavy rainfall. Its maximum flood discharge will probably be in excess of 100,000 cubic feet per second, recent flood discharges having been about 40,000 cubic feet per second. Yet the channel of this river, both in the hills and in the flat lands just

Fig. 9.—Views from land side of a levee during high water.

The sacks of earth are piled along the top of the levee to prevent a break when the levees are overtopped by floods.

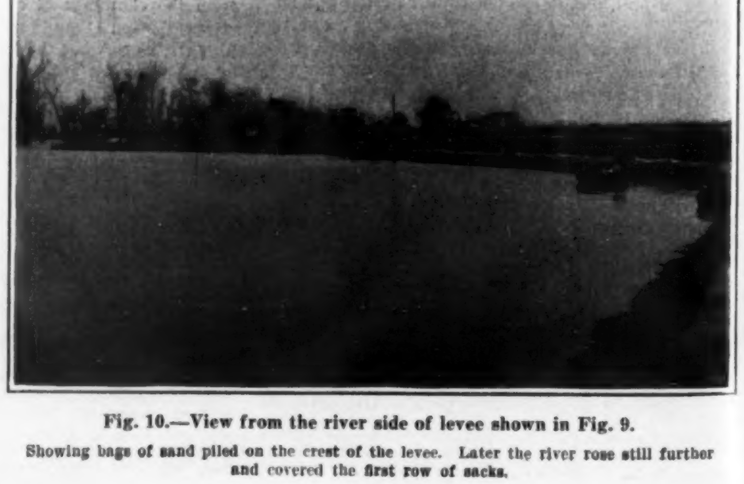


Fig. 10.—View from the river side of levee shown in Fig. 9.

Showing bags of sand piled on the crest of the levee. Later the river rose still further and covered the first row of sacks.

With the breaking of a levee during flood there is a great rush of water as it flows back over the low lands.

If the river were unrestrained by levees it would cover a width of 60 or 70 miles during high water at this point. This is on the west bank of the Mississippi River, in Arkansas.

after leaving the hills, has a capacity of about 900 cubic feet per second, or about 1 per cent of the maximum flood flow. The Castor River, in southeast Missouri, has a drainage area of about 300 square miles. In this case, the well-defined channel in the mountains entirely disappears in the flat lands, where the river loses itself in flat, wet woods. The Red River at the east border of Texas, with a drainage area of about 40,000 square miles, will carry at a bank-full stage perhaps 20 per cent of the maximum flood. The upper Nile River along parts of its course not only has insufficient channel capacity, but actually loses its well-defined channel and becomes a broad marsh covering hundreds of square miles. As a matter of fact, it is very seldom that we find a river which has a channel capacity proportioned to its flood discharge. In nearly every case, this capacity is either excessive or deficient, while in some rivers both conditions occur. For instance, the upper Mississippi in many of its reaches has a capacity several times as great as the maximum flow, while through its lower course at a bank-full stage it will carry perhaps not more than half of the maximum. The Colorado River is another example of the same condition.

The fact is, our rivers are not finished creations purposely fitted to fulfill their proper functions. They are accidental affairs, many of them still in the making. Others, especially those flowing through broad, flat valleys which have been built up by the deposit of silt during overflow, come to a state of equilibrium, where the channel is large enough to carry the usual flow. In such cases, the overflow of the flat lands along the rivers, sometimes over great areas, is a normal condition during high water. All such rivers, if they are to serve their purpose, must be controlled, remade, and managed. The following table gives for several rivers the drainage area, the maximum flood flow, the channel capacities, and the channel capacities as percentages of the maximum flood flow.

Name of Stream.	Drainage area, sq. mi.	Maximum flood flow cu. ft. per sec.	Channel capacity bankfull stage.	Channel capacity as percentage of maximum flood flow.
Coldwater River, Miss. (where it enters the flat lands from the hills)	1,050	100,000	900	0.9%
St. Francis River, Mo. (just south of the Ozarks)	1,550	150,000	8,000	5%
St. Francis River, Ark. and Mo. (on boundary between the two States)	1,600	160,000	500 to 5,000	0.3% to 3%
Black River, Mo. (at foot of Ozarks)	1,450	140,000	4,000	3%
Castor River, Mo. (at foot of Ozarks)	300	35,000	No channel	....
Red River, Ark. and Tex. (at State line)	40,000	350,000*	60,000	17%
Miami River, Ohio (above Dayton)	1,100	120,000†	12,000	10%
Miami River, Ohio (in Dayton)	2,550	240,000†	60,000	25%
Miami River, Ohio (just below Dayton)	2,550	240,000†	15,000	6%
Miami River, Ohio (below Hamilton)	3,500	300,000†	25,000	8%
Scioto River, Ohio (at Columbus)	1,570	140,000†	30,000	21%

*Flood of 1908. †Flood of March, 1913.

In the case of the Black River in Missouri, of the Coldwater River in Mississippi, and of the Red River in Arkansas and Texas, it has been almost impossible to bring some of the interested people to believe that they have on their hands serious problems of river control. So certain are they that it is the divinely appointed function of a river to carry away the water, that many of them believe no improvement is needed except the cutting of a bend here or there, the construction of a moderate levee along the banks, the clearing of brush from the channel, or the removal of sand bars.

In the Miami Valley, in Ohio, the popular habit of attributing all flood damage to obstructions in river channels, especially through the cities, is one of the principal difficulties to be overcome in planning flood

Fig. 5.—Mad River at low-water stage just below Springfield, Ohio, about twenty-one miles above Dayton.

At low water stage the river is here about 5 feet deep. The natural channel is about 200 feet wide between banks which are about 5 feet above low water stage. In the flood of 1913, the banks were submerged to a depth of about 15 feet.

Fig. 8.—During the flood the Mississippi River here is many miles wide, merging with the Yazoo River in Mississippi and with the Arkansas River in Arkansas.

This illustrates conditions described above, where the natural channel of the river can accommodate but a small percentage of the water collected during flood periods, and the overflowing surplus spreads out over many miles of low adjoining country.

protection works. As a matter of fact, in the lower Miami Valley channel capacities within the cities have been maintained and increased until they are to-day much greater than the capacities of the river outside of the cities. Through the main part of the city of Hamilton, Ohio, the capacity of the channel at bank-full stage is about 90,000 cubic feet per second. Above and below Hamilton through agricultural lands where the river channel has been neither improved nor encroached upon it has a capacity at bank-full stage of about 25,000 cubic feet per second. Through the city of Dayton, the river channel has a capacity at bank-full stage of about 60,000 cubic feet per second, and within the levees of about 100,000 cubic feet per second. Through the agricultural lands below the city, where the natural channel capacity has been neither diminished nor increased, the river at bank-full stage will carry 15,000 to 20,000 cubic feet per second. As the discharge during the flood of 1913 was about 250,000 cubic feet per second at Dayton and about 350,000 cubic feet per second at Hamilton, it can be seen that the channels of these streams in their natural unimproved conditions have a capacity of less than 10 per cent of the extreme flood flow, and that through the cities they have capacities of about one third of the extreme flood flow. Under such conditions, determined by actual channel measurements and by stream gagings, it is not correct to assign channel obstructions as the chief cause of flood damage in the cities.

In some cases care has not been taken in determining the cause of flood damage. Take, for instance, a report by U. S. Engineers on conditions at Miamisburg, Ohio, on the Miami River. A little more than a mile below the lower limits of this city the river valley is crossed by a high railroad embankment, which was not overtopped during the flood. The surface slope through this part of the river averaged about 3 feet to the mile. Very careful measurements at the main bridge opening through this embankment show that the water above the embankment at the bridge was 3½ feet higher than below the embankment. The flood level at the lower limit of the city was 4 feet higher, and at the upper limit of the city 11 feet higher than at the upstream side of the bridges, these differences in elevation having been determined by careful measurements. It is evident that this railroad embankment had but little, if

Representative Cross-Section of Miami River in the City of Dayton, O.


Representative Cross-Section of Unimproved Channel of Miami River below Dayton, O.

any, effect upon river stages in the city where the flood elevation was 4 to 11 feet above the flood elevation at the upstream side of this embankment; yet the following statement appears in the above mentioned report: "It seems clear that the long and massive embankment below the town was the primary cause of the extreme high water, which was said to be from 9 to 11 feet higher than the previous record of 1898. This embankment was built within the past few years and this is the first test by flood." Such a statement, made without ascertaining the facts, leaves behind a residuum of misinformation which must be overcome, especially when the name of the U. S. Government adds prestige to the error. As a matter of fact, the reason why the flood stage in 1913 was 9 to 11 feet higher than that of 1898 is that the discharge in 1913 was about 250,000 second-feet as compared with about 90,000 second-feet in 1898, the entire flow having to pass through a very narrow point in the valley between hills. It should be noted that this bridge and embankment formed one of the most extreme cases of channel contraction to be found in the entire flooded district, and that in few, if any other cases, has any single obstruction caused as great a difference in elevation.

A careful study of many other situations where flood damage is blamed upon obstructions in the stream channel or in the flood plain will, in general, give the same results; that is, they will show that unless actual measurements and careful examinations are made, the almost universal tendency is to greatly exaggerate the effect of isolated obstructions upon flood stages.

The following quotations from Ohio papers, in opposition to flood prevention works, indicate the extent to which this misconception has been carried:

"It is well known that had our rivers been cleared out and not been encroached upon there would have been no such flood as the one which visited us last March. To neglect in a large measure can much of that terrible inundation be ascribed."—*Troy News*, January 22nd, 1914.

"Dayton's predicament is due to its own greed and lack of foresight. It has builded upon made land which nature formed as a waterway and aside within the past generation or so, encroached upon the river and filled the stream with sub-structure that the waters now have little chance to get through."—*Troy News*, February 27th, 1914.

"Dayton has stolen the channel of the Miami River from the people of the valley and now is trying to hold on to the stolen property and at the same time secure protection from future floods at the expense of the people of all the counties north of Dayton in the great Miami watershed."—*Troy Record*, March 12th, 1914.

These and many similar references are particularly inappropriate in the case of a city which has so improved and protected its river channel as to provide four times the capacity that is provided in the unimproved channel below.

In flood prevention works we should distinguish between rivers having ample channel capacity which never overflow their banks, but which cause flood damage because the actual channel is encroached upon more and more until the flood channel is invaded; and the other type of river which, while having a definite low water channel, flows through a wide flat plain that is overflowed during floods. The lower Hudson, the upper Mississippi and the Potomac are typical of the former, and the lower Red, Arkansas, White, Yazoo, Miami and Tensas rivers, and the Red River of the North, of the latter. In the former cases flood prevention may best be secured by retreating from the flood plain and removing all improvements to higher ground. In the latter cases relief lies in controlling floods so that flood plains are protected.

In very many cases the obstruction of channels has had much to do with flood damage, and the need for effective supervision to prevent further obstruction is becoming more and more urgent. Most European states now exercise strict control of river channels, but European cities are still suffering for the sins of the past. While giving due weight to these considerations, we should not forget that in the case of many rivers the primary cause of floods is that the rivers in their casual development have not dug for themselves large enough channels to carry flood waters.

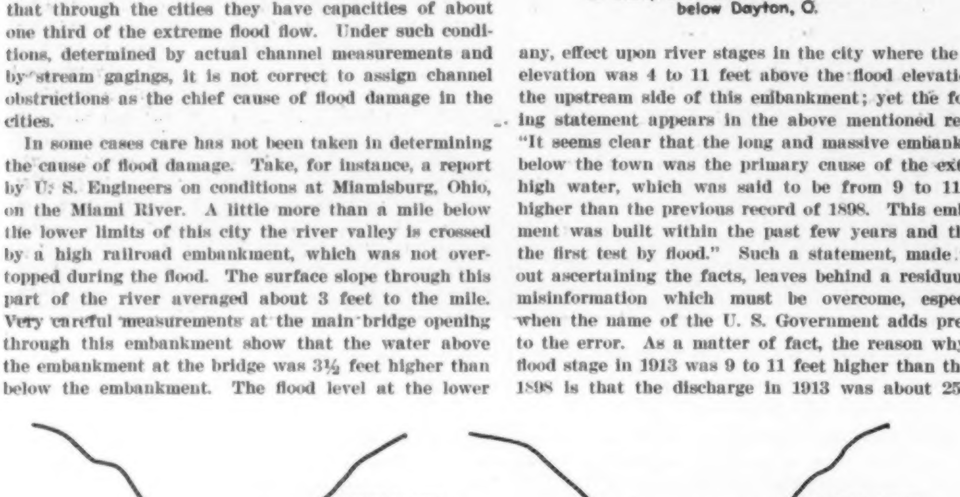


Fig. 1.—Hudson River, near Mechanicsville, N. Y. Ordinary discharge 6,000 cubic feet per second; flood discharge, 110,000 cubic feet per second. Fig. 2.—Grand Canyon of the Colorado, Hardyville, Arizona. Ordinary discharge, 47,000 cubic feet per second; flood discharge, 100,000 cubic feet per second. Fig. 3.—Mississippi River, near Clayton, Iowa. Ordinary discharge, 40,000 cubic feet per second; flood discharge, 450,000 cubic feet per second. Fig. 4.—Mississippi River, near mouth of Red River. Ordinary discharge, 200,000 cubic feet per second; flood discharge, 2,500,000 cubic feet per second. (Approximate bank full capacity, 1,000,000 cubic feet per second.)

Cross-sections of various types of river valleys.

Development of Return-Tubular Boiler Furnace*

By Osborn Monnett †

After using steam jets, the next step in the attempt to keep down smoke in the furnace of a tubular boiler was to build an arch over the combustion chamber back of the bridge-wall, somewhat as shown in Fig. 1. In connection with the steam jets the arch was an improvement, as it broke up the gases and mixed them to a certain extent. However, this design lacked several essential features of a successful furnace, the principal objection being that it did not provide sufficient temperature at the point of mixture. The heat absorption into the boiler was sufficient to reduce the gas temperature to such an extent as to impair combustion of the volatile matter.

An elaboration of this design was the old so-called McGinnis arch setting, which was in quite common use fifteen years ago. This consisted of two arches, one back of the bridge-wall and another over the grates in front of the bridge-wall, as in Fig. 2. This was an improvement over the former setting, because the gases were mixed more thoroughly and the setting gave good service until smoke began to be read more closely. A peculiarity of the setting is that the gases passing under the front arch must make one turn upward over the bridge-wall, another turn along the shell and then come in contact with the back arch, where another change in direction occurs. This will be apparent from an inspection of Fig. 2. Given careful attention, with a judicious use of the steam jets, this setting, while not considered in any sense modern, will give fairly good results. The same objection as to temperature of gases exists and detracts from its efficiency.

Another setting popular in the Middle West from 1885 to 1907 was the Gulickson, shown in Fig. 3. This consisted of a double arch over the bridge-wall with another single-span arch back of the bridge-wall. This construction split up the gases as they passed over the bridge-wall and to some extent mixed them at the second arch. Modifications of the above designs were made without number in an attempt to satisfy the public in the matter of smoke suppression. These attempts embraced various designs of so-called pigeonhole bridge-walls, wing-walls, piers, perforated drop arches, bulkheads, etc., but in nearly every case one or more of the essential features of a successful furnace were missing. All of the above settings were in use up to about 1907,

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† Smoke inspector, city of Chicago.

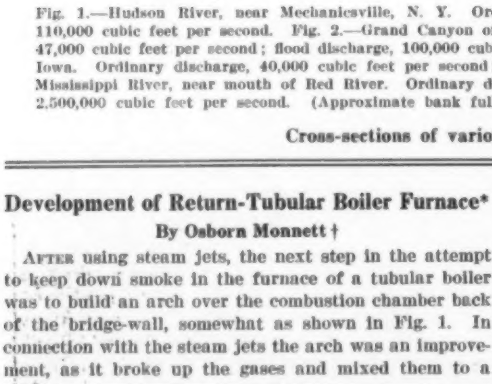


Fig. 1.—Return-turbular with single-span deflection arch.

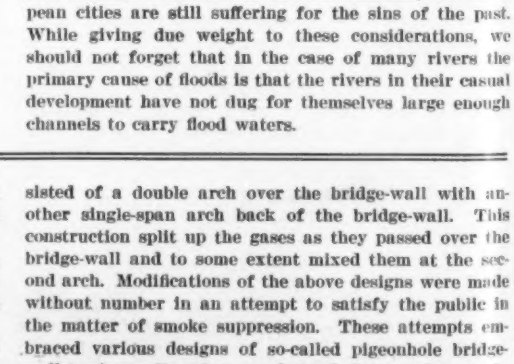


Fig. 2.—McGinnis arches in front and back of bridge wall.

when the subject was taken up seriously in Chicago by the Department of Smoke Inspection as at present organized.

The best authorities at this time advised surrounding the fire by brickwork and thus maintain a high temperature to increase the ignition and provide a long-flame travel during which combustion could be made complete before the gases came into contact with the heating surface. A number of firebrick-inclosed furnaces of the dutch-oven type were built, some full extension and some half extension, but the majority were flush front, as shown in Fig. 4. At first they were built without and later with a slight drop arch behind the bridge-wall. These settings were not satisfactory, but furnished the information which led to the present ideas on hand-fired furnaces. With these dutch-oven settings the initial expense was high and a great deal of the heating surface in the shell was covered up, with consequent loss of capacity and efficiency, and the setting proved to be difficult to run without dense smoke. It soon developed that mere flame travel in hand-fired furnaces was not sufficient to produce good combustion. It was shown that even where the path of the gases from the grates to the heating surface was excessive, if there were not in this path some form of mixing arrangement that

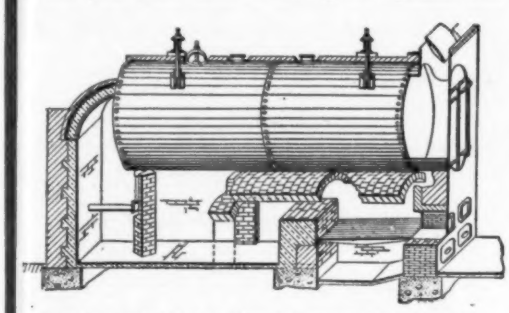


Fig. 4.—Firebrick-inclosed furnace with single-span deflection arch.

would abruptly change the direction of the gases and bring them into intimate contact, a stratification would take place and smoke would be made. The deflection arches as then built were high and accomplished imperfectly the result sought. They were afterward built lower and lower to get more positive mixture, but still there was smoke.

The radiating effect from an intensely hot arch over the fire distilled the volatile matter from the fuel more rapidly than it could be mixed with air and consumed

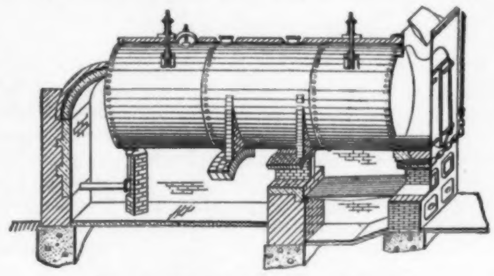


Fig. 3.—The Gulickson setting.

in the furnace. In fact, the furnace had a "muffle oven" effect, and puffs of dense smoke were made in spite of the greatest care in operation. Finally, when it became evident that the furnace was not adapted to high-volatile coals, the arches over the fire were removed to reduce the temperature of ignition with a consequent reduction in the rapidity of distillation of the volatile matter. This resulted in a construction similar to that shown in Fig. 5, which is known as the Department No. 4 furnace, consisting of an arch sprung over the bridge-wall and extending back some 3 feet, with a deflection arch to mix the gases. This furnace increased the heat absorption into the boiler by direct radiation from the fire; decreased the rapidity of distillation of the volatile matter by reducing the igniting effect, and resulted in a furnace much easier to run without smoke. A few dutch-oven furnaces equipped with special air admission have survived. They generally burn a picked egg coal, and with careful attention to the air supply have succeeded in running clean.

Experiences with the No. 4 furnace, and those that came after it, gradually developed the theory upon which is founded the design of modern hand-fired furnaces as used by the Chicago Smoke Department for high-volatile coals. It became evident that ignition was not necessary to burn this kind of coal; draft was the main essential. As evidence of this, a locomotive with a plain firebox without a brick arch can burn with ease 100 pounds of coal per square foot of grate surface per hour without any ignition except that furnished by the fire itself, because the draft is adequate for the purpose.

In the next place, it was found that a "cool" furnace (one having direct radiation from the fire to the heating surface) not only increased efficiency and capacity by increasing heat absorption, but reduced the liability to dense smoke because the volume of volatile passing off was at no time in excess of the capacity of the furnace to take care of it. All that was necessary then was to provide a zone of high temperature back of the bridge-wall which would maintain the gases at or above the igniting temperature; then provide a deflection arch against which the gases would impinge at this high temperature, and finally, provide air admission over the fire in sufficient quantity to mix in the high-temperature zone with the volatile gases and furnish the necessary oxygen for complete combustion. As from 30 to 35 per cent of the weight of the fuel is in the form of volatile gases, the air necessary to form a proper mixture must be admitted over the fire. With the ordinary drafts encountered in stationary practice, it has been repeatedly demonstrated that it is impossible to draw sufficient air through the grates to completely burn the volatile matter. The term "excess air" ordinarily applied to

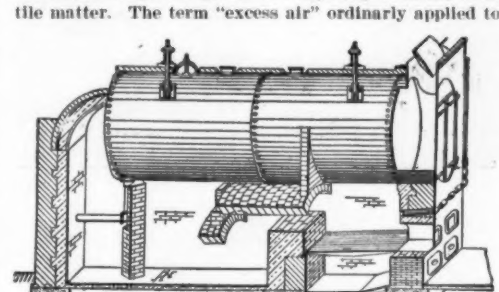


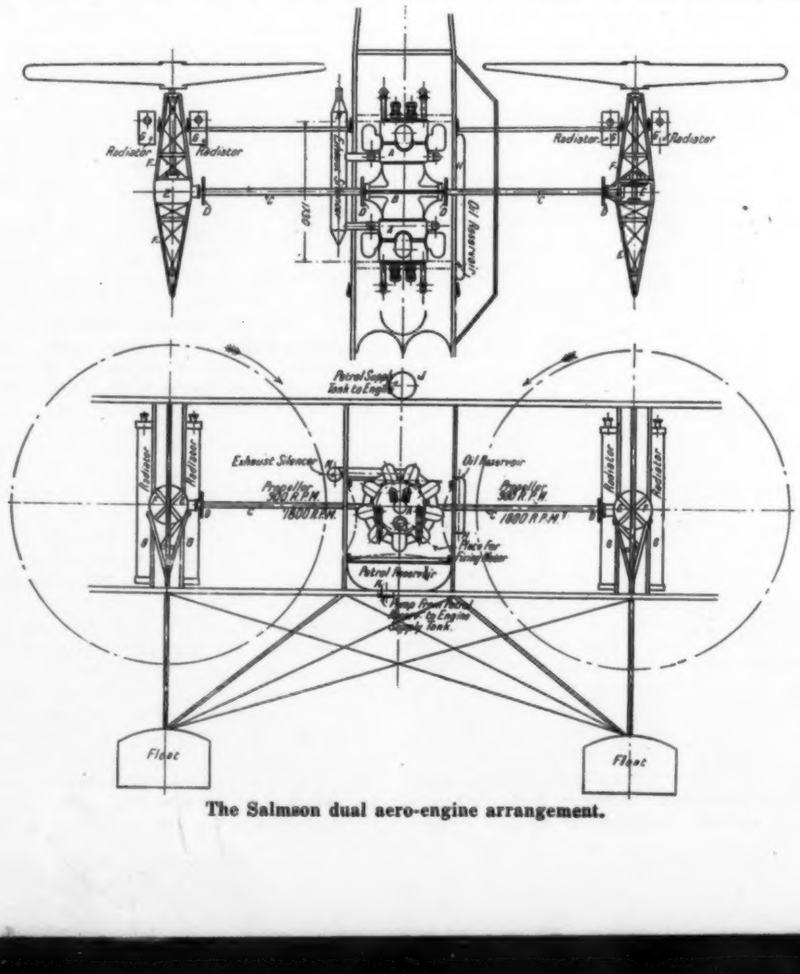
Fig. 5.—Single-arch bridge-wall furnace, with single-span deflection arch (No. 4 furnace).

air being admitted over the fire, is not in any sense in excess of the air required to burn the fuel, as it must be remembered that a large proportion of the fuel is in the escaping gases, and it must have this air to be completely consumed.

Dual Aeronautical Motors

To make aeroplanes of value for practical purposes it has been realized that much greater motive power will have to be installed than has heretofore been considered necessary. In this situation the following description of a high power installation, from *The Engineer*, London, will be read with interest:

Herewith we illustrate an arrangement that is being adopted on dirigible balloons and aeroplanes, in which two propellers are used, each driven by a separate engine. Each engine has nine cylinders in the example illustrated, and develops 300 horse-power. As designed for an aeroplane, the arrangement may appear enormously powerful. Nevertheless, 600 horse-power on one machine has already been approached by the Russian designer Sikorsky, while in France a military biplane actually intended to utilize the arrangement herewith illustrated is, we have reason to believe, under construction. It may be noted here that, although these dual engines provide together 600 horse-power, it does not necessarily follow that both engines will normally run simultaneously. They can do so if desired, but means are provided whereby either engine may be employed to drive both propellers, while the other engine is kept idle as a standby in case of breakdown or emergency.



The Salmson dual aero-engine arrangement.

The motors shown at *AA* are each complete in all details. Each has its own radiator, pumps, magnetos, carbureters, etc. The engines are mounted on pressed steel plates, the distance between which is 1.73 meters. These frame plates are supported on eight adjustable buffers designed to enable the engines to be readily fixed in place and to distribute the dead weight and working stresses uniformly to the car framework. Between the motors a change gear box *B* is arranged. This box not only reduces the speed, but provides means whereby either or both propellers may be driven by either or both engines. The details of this gear have not been divulged to us, but we understand that they include two clutches and two coupling devices, the former being operated by a balanced lever and the latter by a hand wheel.

From each side of the box a shaft *C* extends at right angles to the engine crankshaft. Flexible plate couplings are provided on these shafts at *DDDD*. The ends of the shafts are led into reduction bevel gear boxes *E* supported on special fuselages *F*, through which pass the propeller shafts. These fuselages are designed to absorb the reaction stresses produced by the right-angled transmission in the boxes *E*. The radiators *GGGG* are in two parts for each motor, and are situated just in front of the propellers, where they are subjected to a good draft.

An oil reservoir *H* supplying both motors is fixed to the side of the cab framework, where it is kept cool in the draft of air. Beneath the motors is the main gasoline reservoir *I*. A gravity feed to the carbureters is obtained from the supply tank *J* overhead, the capacity of which is 70 liters. Fuel is delivered from the reservoir to the supply tank by a pump *K* driven through vertical gearing from the motors. An exhaust silencer *N* is fitted outside the cab and is common to both motors.

The propellers, it will be noticed, rotate in opposite directions. They are 4 meters in diameter and run at 900 revolutions. The shafts *C* run at double this speed, and the motor crankshafts at 1,200 revolutions. The speed is therefore first stepped up and then down.

The weights of the items in this arrangement are approximately as follows: Two engines, each 8¾ hundredweight, 17½ hundredweight; one clutch and coupling box, 4½ hundredweight; two sets of radiators and gear, 3½ hundredweight; one supporting frame, 1½ hundredweight; total, 27 hundredweight.

Artificial Daylight—I*

Light Sources Suitable for Color-Matching

By Herbert E. Ives

In the fourteenth century the Glovers' Company of London decreed that "no one shall sell his goods by candle light." When Tyrian purple was the staple cargo of the galleys of Phœnicia, it is safe to say that the buyers of that day early learned by experience to make no purchases by torchlight. Certainly it has long been known among those whose business it is to work with colors that daylight and "yellow candle light" are wide apart, not only in appearance, but also in their effect upon colors. It comes, nevertheless, as a surprise to many to learn how numerous are the industries whose working hours depend upon daylight. Color printing and lithography, dyeing, the painting and viewing of pictures, tobacco sorting, the grading of sugar and flour, the sorting of precious stones, the matching of colored fabrics, the inspection of meats and delicate chemical analysis—these are a few having need for daylight at all hours, to say nothing of the surgeon and the dentist.

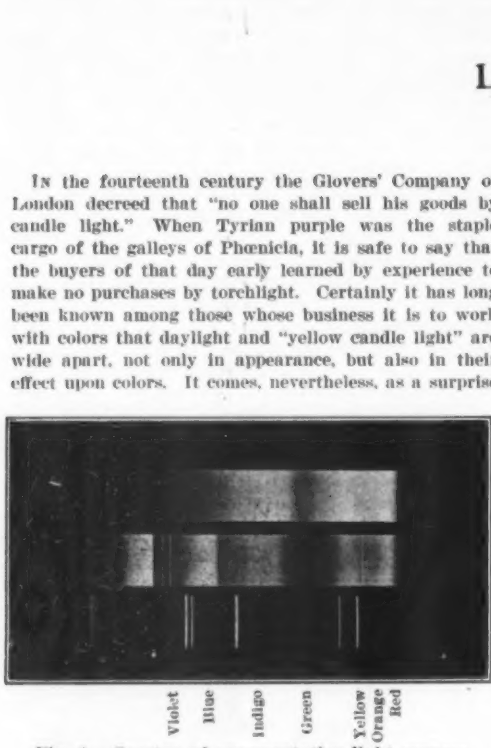


Fig. 1.—Spectra of representative light sources.

a, Continuous spectrum of the Welsbach mantle; *b*, continuous spectrum with superposed bands, carbon arc; *c*, line spectrum of the mercury arc.

Among women a knowledge of the defects and pitfalls of artificial light is more general than among men, doubtless because the prevailing fashions call for color in feminine attire. In a big store any day, almost any minute, one may see prospective purchasers of dress goods carrying pieces of goods, or having them carried, to the more or less distant windows to learn their true daylight appearance. For a dress must not look well merely by the artificial light over the counter, but out of doors as well, and frequently is good by one and inharmonious or ugly by the other.

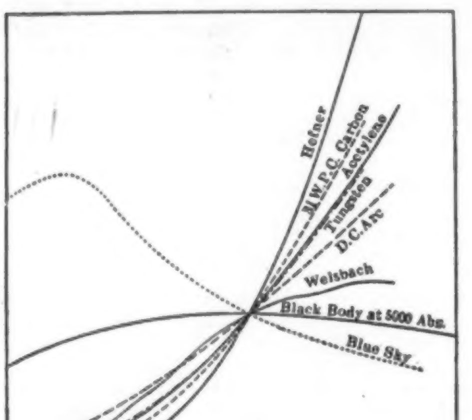


Fig. 2.—Relative intensities through the spectrum of certain representative illuminants.

The fact that, as a rule, artificial light is greatly different in appearance from daylight need be merely noted at this point. Most artificial lights are more or less yellow as compared with the light of the sun or sky. The difference is usually very great, as anyone can convince himself by comparing the two side by side under conditions of approximate equality of brightness for the two. For instance, if two shadows of a pencil are formed side by side by the two kinds of light, such as a tungsten lamp and the sky, the shadow illuminated by artificial light appears orange yellow; that by the sky, deep blue by contrast. Ordinarily we do not appreciate this difference because we do not see the two lights together, and because, if the artificial light is not too strongly colored, the eye by the process of adaptation will in large measure adjust itself to the new distorted color scale—just as a man in walking against the wind unconsciously leans forward. There is a large and interesting problem here for the physiologist and the psychologist to answer: in what way and how much the use of artificial light so different in quality from the light under which the race has been developed may affect the eye and the mind. Certain it is that artificial light is not an unmixed blessing. To its increased use is popularly ascribed many eye troubles. Then, too, many of our habits as social animals seem intimately connected with the use of artificial light. Whether it be the glitter and heat of our ballroom lights, or the odor and dimness of our midnight oil, that work their characteristic stimulation, benefits, depression, or ocular injury, or whether these are to be ascribed to their color, is a problem of interest, but here we shall concern ourselves almost entirely with the severely practical question of producing artificial daylight for industrial purposes.

What is daylight? is the inevitable question, for it is at once evident that the setting sun, a clear blue sky, and a "white" cloud are markedly different. So, too, the light reflected into our buildings from snow, grass, foliage, from earth, brick pavements, or gray asphalt is far from being a uniform thing. Daylight is, in fact, quite variable in color, a fact which has led professional color matchers to search for the most constant kind of daylight. This they have decided to be the light from a clear north sky. To the eye this is unmistakably blue in color, hence the problem of producing daylight is not necessarily the same as that of producing "white" light.

In order to answer the question, "What is daylight?" it becomes necessary to measure color. We shall, therefore, first pay some heed to the scientific measurement of color. We shall then apply the methods of color measurement to our present illuminants, natural and artificial, and so learn how they differ from each other. Various ways of producing artificial daylight will present themselves as a result of this study and will be discussed. Next we shall investigate the problem of why and how colors change in appearance in going from one kind of light to another. From this we shall be led to formulate the necessary characteristics of a color-matching artificial daylight. Some account of the practical achievement of artificial daylight, its various forms, and its characteristics, will follow. Then a little space will be devoted to a study of the distribution of natural daylight out of doors and in rooms, and the possibility of our ultimately copying, at a not prohibitive expense, both the color and the distribution of natural daylight.

COLOR MEASUREMENT.

There are two distinct methods of color measurement. The first is by analysis of the light radiations into their elements and then quantitative measurement of these elements. The second is by analysis according to the effects on the visual apparatus. Properly speaking, the first method is not color measurement at all, since, as will be seen, a color-blind observer or a thermometer, if sensitive enough, may be used to make the measurements. Nevertheless, our problem is an indeterminate one without such measurements, so that they must be treated in detail.

As everyone knows, light may be analyzed or dispersed by means of a prism or grating. Sunlight, when so dispersed, gives the rainbow or solar spectrum with its numerous colors, of which the principal ones are red, orange, yellow, green, indigo, blue, and violet. Any complete study of color must be a study of colored light, since it is only by seeing colored light that we appreciate objects as being colored. The color of an object is, in fact, determined by the completeness with which it reflects or transmits the light which falls upon it. It owes its color to the existence of that color in the light illuminating it. A red glass is red because it transmits the red of the spectrum. For this reason the whole story of an illuminant's behavior as a revealer of color is laid bare when once the light of the illuminant is analyzed completely. These analyses may be considered in two parts—qualitative and quantitative. Qualitatively we note important differences in the spectra of different light sources. Sunlight, for instance, gives a continuous spectrum with no noticeable breaks from red to violet. A candle gives a similar spectrum, but one which will give us some difficulty in seeing the blue and violet portions, unless we arrange our prism device (spectroscope) in a way favorable to bring considerable light to the eye. A carbon arc light shows a continuous spectrum, but one on which are superposed bright violet lines or bands. A nitrogen vacuum tube exhibits several isolated broad bands of colored light. A carbon dioxide vacuum tube shows numerous fine lines and bands nearly filling the entire spectrum. A mercury arc, representing the extreme from the continuous spectrum, exhibits merely isolated bright lines of light. In short, in the incandescent mercury vapor only comparatively few vibrations are represented, which when communicated to the ether produce light waves of those few wave-lengths only (Fig. 1).

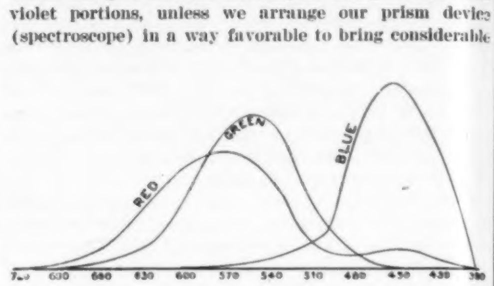


Fig. 3a.—Color sensations in white light.

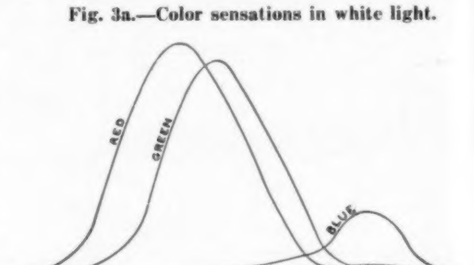


Fig. 3b.—Color sensations in incandescent carbon lamp light.

Considerable information bearing on our special problem is furnished by this merely qualitative survey. It is at once evident that a light totally lacking in any color of the spectrum, such as the mercury arc, which is lacking in red, is not capable of showing that particular color in an object. But this qualitative knowledge must be supplemented by quantitative measurements before it has any real use. Such measurements are usually made by the spectrophotometer, which is, in brief, a spectroscope so arranged that each color may be compared in intensity with the same colored light from a chosen standard light. In place of a standard light it is much preferable to reduce the results to an absolute standard, i. e., to obtain the intensity of the radiation at each wave-length as indicated by the heating effect. The values which are given here have been so reduced as to show these energy values, as though they had been obtained by the use of a bolometer or thermocouple at the observing slit of the spectrometer.

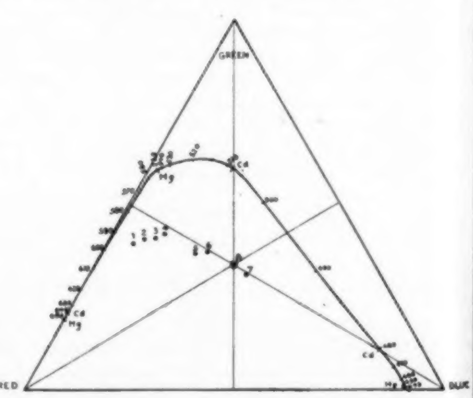


Fig. 4.—Color triangle, showing positions of spectrum colors and representative illuminants.
1, Hefner; 2, carbon; 3, tungsten; 4, Welsbach; 5, D. C. arc; 6, afternoon sun; 7, CO_2 tube; 8, whole light.

Fig. 2 plots in the form of curves the relative inten-

*Paper read before the Franklin Institute and published in its *Journal*. Copyright, 1914, by the Franklin Institute.

ities throughout the spectrum of certain representative illuminants, including sunlight and blue sky, these latter being the mean of a number of observations by different people. The curves as drawn equal 0.59μ, which is merely a matter of convention, since the actual relative intensities of the lights are not involved. As a matter of fact, this convention practically means that the lights compared are at nearly the same luminosity.

An examination of these curves yields interesting information. Practically all the common artificial illuminants differ from daylight in having an excess of red, orange, and yellow radiations, with a corresponding deficiency in blue and violet. They lie together in an entirely different family from the varieties of daylight. The latter differ in the blue on this scale by less than the factor two, whereas the ratio between day and the artificial lights is from six to twelve. The physical explanation of this lies in the fact that the common illuminants are incandescent solids at comparatively low temperatures, such as 1,500 to 2,500 deg. K., while sunlight approximates in color an incandescent solid or black body at 5,000 deg. K. The practical effects of this characteristic of the common illuminants, such as the incandescent electric lamp, the Welsbach mantle, the gas flame, etc., are two: First, their general yellow color, and, second, their different effects on colored objects. This latter peculiarity will be treated presently.

The second method of color measurement must now

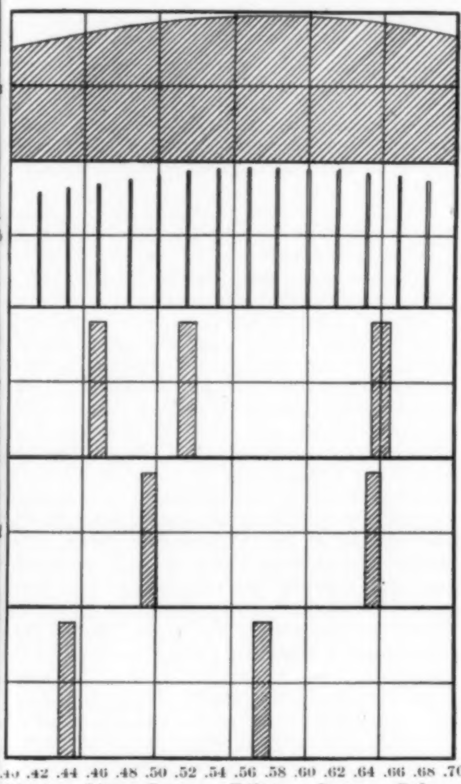


Fig. 5.—Various ways of making white light.

a, Continuous spectrum; *b*, a large number of lines or bands; *c*, a mixture of red, green, and blue; *d*, a mixture of red and blue-green; *e*, a mixture of yellow and blue.

be considered. This is derived through color-mixture experiments. It owes its significance to the important fact that colors may look exactly alike which are, nevertheless, composed of quite different radiations, as indicated by the spectroscope. For instance, a mixture of red light and green light produces a yellow which is indistinguishable in hue from a true spectroscopic yellow, i. e., a color showing nothing but a small region of the spectrum around the yellow. Similarly a mixture of yellow light and blue light produces a white indistinguishable from one in which all the spectrum colors are present. Red and bluish green constitute another part of these "complementaries," as they are called. The most interesting set of mixture colors, however, are red, green, and blue, for it has been found that from these three may be made not only white, but all the colors of the spectrum, and hence all the colors formed by the addition and subtraction of these; that is, all the colors of Nature. It must be clearly understood, however, that these color matches are subjective; that is, they look the same, but of course on analysis with the spectroscope they at once show their composite character.

Now this characteristic of red, green, and blue light has led to these colors being called "primaries." They constitute the smallest number of colors out of which all the others may be produced. As such they have had a notable part in making color photography possible. Here we are more interested in the fact that these phenomena of color mixture furnish a method of measuring and representing colors as they appear to the eye, irrespective of their composition.

Taking the spectrum of white light as our standard, it is possible by a series of experiments to determine

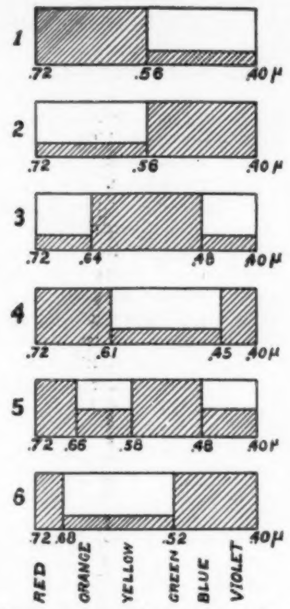


Fig. 6.—Spectral composition of certain arbitrary colors; reflecting power of surfaces or transmissions of absorbing media.

the quantities of red, green, and blue necessary to match each of the other spectrum colors. Curves may thus be plotted representing these facts, and are called color-mixture curves of the spectrum. This has been done, and it has been found that the true primaries are a certain red, green, and blue a little purer and more saturated than any ordinarily found in the spectrum. These experimentally indicated true primaries are called the primary or fundamental sensations. Fig. 3*a* shows their distribution in the spectrum, where the units are chosen such that equal quantities of the three sensations give white.

A color may now be specified in terms of but three quantities, instead of a dozen or more, as is necessary with the spectrophotometer. White is equal quantities red, green, and blue sensation; yellow is so much red sensation and so much green, as may be read off the curves. A complex color such as that of an illuminant may be evaluated by multiplying its spectrophotometric value at each wave-length (as compared with white light) by the values of the three sensations at the corresponding wave-lengths and then integrating the curves. Thus the values derived by the use of the spectrophotometer may be translated into sensation values. This transformation process is indicated by the curves of Fig. 3*b*, in the case of a carbon incandescent lamp.

Still another way to obtain the sensation values is by actually making mixtures of red, green, and blue light to match the color under measurement. If one knows the sensation values of the red, green, and blue lights mixed, the results may be at once translated into terms of the fundamental sensations. Some results of transformations to color sensations from both kinds of measurements of color are shown in the color triangle, Fig. 4.

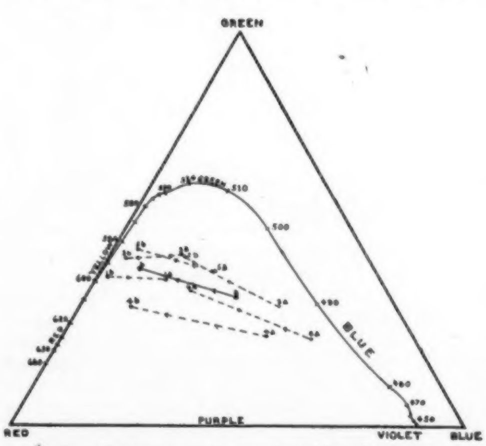


Fig. 7.—Change in color produced by change from daylight (a) to carbon incandescent lamp illumination (b).

The results of measurements in terms of color sensations lend themselves to an elegant and useful diagrammatic representation in what is called the Maxwell color triangle, which we shall have occasion to use later. This triangle is shown in Fig. 4, where the three fundamental sensations are indicated at the three vertices, white at the center and the various spectrum colors in their appropriate positions around the triangle. A certain property of an equilateral triangle is here utilized; namely, that the sum of the vertical distances of any point from the three sides is equal to the altitude. If, then, the three sensations which constitute a color be represented in such units that their sum is the altitude of the triangle, every color finds a place in it. White, being equal parts of the three sensations, lies at the center.

An interesting and valuable property of the triangle is that mixtures of two colors lie on the line joining them. Thus the yellow lies on the line joining red and green. White lies on the line joining a large number of pairs of colors, the "complementaries" met with above. We can then read off from this triangle what colors are to be mixed to produce any others, among them white.

The various sensation values for different illuminants are plotted in the triangle of Fig. 4. This plot again shows how most artificial illuminants differ from white toward yellow, as they are much nearer the yellow of the spectrum than the white center.

METHODS OF MAKING WHITE LIGHT.

As a result of the study of color measurement several methods of artificially making white light present themselves. First and most obvious, theoretically, is the production of an illuminant that has the same distribution of intensity throughout the spectrum as a chosen daylight standard. For instance, if the standard be taken as the color of an incandescent solid at 5,000 deg. Cent. absolute, the direct way to make artificial daylight would be to heat a solid to such a temperature. This, of course, we know is impossible with our present facilities for high temperatures and our known refractory substances. Some form of selective radiation, as from certain oxides as yet unstudied, or from gases under electrical discharge, must then be looked to as a possible means of securing directly, without prohibitive

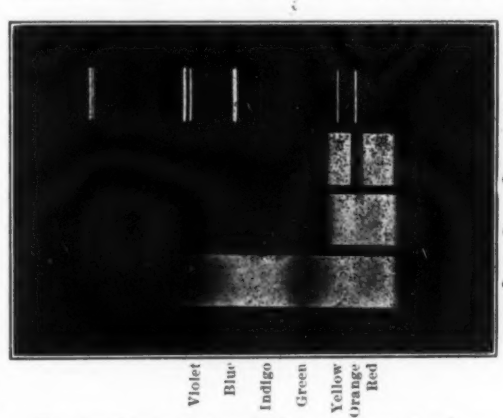


Fig. 8.—Cause of change of appearance of colors of different compositions when viewed under different illuminants.

a, Continuous spectrum light source; *b* and *c*, two yellow solutions which appear exactly alike when illuminated by light source *a*; *d*, line spectrum. Solution *c* absorbs one of the principal lines of this spectrum and consequently appears different in color from *b*.

temperature, the desired energy distribution in the spectrum.

A second method is to subtract, as by a process of absorption, those radiations in an illuminant which are present in excess over daylight. The manner of accomplishing this theoretically is indicated by Fig. 11, where an ordinary artificial illuminant (excess in red, orange, and yellow) is to be made to match daylight. Starting with a point on the extreme blue of the spectrum, progressively greater portions of the illuminant's radiations are to be absorbed, as indicated by the area of the curve above the cross-hatched portion. Assuming the absorption performed, there remains a spectrum identical in every respect to the standard white light.

A third method of producing white light is indicated by the color-mixture experiments; namely, by the mixing of two or three colors respectively complimentary. Fig. 5 shows an illustration of how white light might be made up of (*a*) a continuous spectrum, (*b*) a large number of lines or bands, (*c*) a mixture of red and blue green, (*d*) a mixture of yellow and blue, and (*e*) a mixture of red, green, and blue, the proper quantities of each being taken so that the total of each fundamental sensation is in every case the same.

With these various means at our disposal it becomes necessary to establish criteria upon which the relative merits may be decided. Among such criteria are efficiency and suitability for color matching. The latter requirement is the most important one here, and will next be considered.

THE REQUIREMENTS OF A COLOR-MATCHING ILLUMINANT.

What is the relationship between the color of an illuminant and the color of the illuminated object? An answer in one simple case is straightway evident. If the illuminant lacks the spectrum rays which by reflection from a surface constitute the color of the surface, then the illuminant obviously is useless for revealing whether two such non-reflecting surfaces are the same color or not under other and more usual illuminants. But if all the spectrum colors are present, though with varying intensity, it is not so easy to answer the question at issue. We must have recourse to the methods of measurement above outlined.

Let us take a representative color, such as is to be found in a dyed fabric. With a spectrophotometer determine its reflecting power at each wave-length of the spectrum. If we multiply the values obtained by the values of the sensation curves in two illuminants under study, we arrive at the resultant sensations as excited by the light reflected from the fabric under the two different lights. These values may then be tabulated or plotted in a color triangle showing the change in the color of the surface under the different illuminants. On carrying through this operation for the set of arbitrary colors shown in Fig. 6, under daylight and under carbon lamp light, the color triangle data of Fig. 7 were obtained. It is to be seen that, while pure spectrum colors change not at all (since they have no various spectral components to be altered in relative intensity), the colors nearer white are bodily shifted in hue. Purples become reds, greens turn to yellows, and so on. This illustrates the change of color appearance, which is very marked, for the kind of illuminants compared, with purples and lavenders (which become ruddy), blues (which become black), yellows (which appear less strongly colored). But the question of color matching is the paramount one. If two colors match under one illuminant, will they match under another? The answer is evident if we consider the two possible kinds of matches. If we have two yellows, identical as to reflecting power through the spectrum, obviously they will continue to match under any illuminant, since both will be affected alike. But suppose one of them is a mixture of red and green, the other a spectrum yellow. Under white light they are identical in appearance. But when they are placed under a light different in composition, such as a carbon incandescent lamp, the red element of the composite color is unduly accentuated, the green element insufficiently brought out, and the resultant appearance is not the same as that of the simple yellow. This difference may be shown numerically by the use of the color sensation curves and the color triangles. It is illustrated for an extreme case by the spectrograms of Fig. 8. Here are shown (*a*) a continuous spectrum light (Welsbach mantle), (*b*) and (*c*) the spectra of two yellow solutions which match perfectly under this light, and (*d*) a discontinuous spectrum (mercury arc). Note that the absorption band in the second yellow falls exactly over the yellow mercury line; the mercury arc light viewed through this solution is bright green; through the other solution it is yellow. The two solutions look exactly alike by one light, totally different by the other.

It is obvious, from these considerations, that if an artificial daylight is to behave toward all kinds of colors exactly as does real daylight, it must not only look like daylight, but must be identical with it, wave-length by wave-length through the spectrum.

(*To be continued.*)

The Safe Use of Electricity in Coal Mining*

Conditions Under Which Explosions of Gases and Dust May Result from Sparks

By W. M. Thornton, D.Sc., D.Eng.

At present there are 3,500,000 workers in coal mines throughout the world, and there are few mines in which electricity is not used for signaling, lighting or power. On a conservative estimate, the value of the electrical machinery now being installed every year in coal mines approaches $50,000,000, and with the development of the Chinese coalfields this may be expected to increase; but the possible danger from electric ignition of firedamp or coal dust has only been at all fully considered in the last few years. Within five years there have been three great colliery explosions which have had a possible electrical origin. At West Stanley, in Durham, direct electrical ignition of coal dust by a flash from a faulty fuse box was suggested; at Hulton, in Lancashire, ignition of gas at a faulty switch; at Senghenydd, in South Wales, ignition of gas by the spark on a signaling bell circuit. These disasters have directed public attention to the subject with increasing force, and the present notes, compiled at the suggestion of H.M. Electrical Inspector of Mines, give the more important conclusions which have been reached by recent research. It must be said, however, that there is no class of work in which electricity can be used with more advantage than in coal mining; but to insure safety it is necessary to take precautions which are not necessary above ground. For some years competition lowered the quality of electrical mining gear below that on the surface. This is now less usual, and the quality of mining work is in many cases better than surface work, and I am told is especially good in the latest installations in Manchuria. With regard to danger from electric shock, there is nothing peculiar to coal mining, and the risk is not here discussed.

Lower limit of ignition of gas.—The initial ignition in most colliery explosions is of firedamp alone. For this to occur sufficient gas must be present to form a lower limit mixture. If the combustible gas is pure methane (CH_4), the lower limit of inflammability is at 5.6 per cent of gas in air by volume at atmospheric temperature and pressure.[1] If, however, there is ethane or other higher hydrocarbon present, the limit is lowered in inverse ratio to the heat of combustion of the mixture. The calorific value of methane is 189.1 and of ethane 336.6 kilogramme-calories per gramme-molecule. Thus, a mixture in which ethane formed 30 per cent and methane 70 per cent of the combustible gas would have a lower limit of inflammability at 4.5 per cent of gas in air. Such large fractions of ethane are unusual in most large coalfields.

Influence of Temperature.—The most recent work on the influence of temperature on limits of inflammability is that of M. Taffanel, of the French Coal Dust Research Station at Lievin, and M. Le Floch. They have shown[2] that as the temperature is raised the lower limit of inflammability falls. In the case of methane values are given in Table I.

These are of interest in the case of heat from gob fires, but electric arcs from breaks are transient and local,

TABLE I.

Initial temp., Cent....	20°	175°	237°	312°	555°	690°
Lower limit........	5.8	5.25	4.75	4.3	3.4	3.0

and we may, in the absence of coal dust, take 5.6 as the lower limit in electrical coal mining practice. It will be shown later that even one half per cent of gas with sufficient dust present helps to forward an explosion.

The Most Inflammable Mixtures.—The usual measure of inflammability of a mixture between the limits has been by the velocity of an explosion wave in it, but the measurements are difficult to make. For the purpose of safeguarding the use of electricity in mines a more convenient test is to find the electric current which, when broken in the mixture, causes ignition by its break spark. The results, using non-inductive circuits—that is, with power factors not less than 0.95 when the current is alternating—are as follows for methane and ethane:[3]

Table II.—*Methane.*

Percentage of gas in air by volume.	Least igniting current.	
	Continuous at 100 volts.	Alternating at 40 ∼ 200 volts.
5·6	Lower limit	
5·0	1·9	12·5
7·0	1·20	7·5
8·0	1·0	4·9
9·0	1·07	3·2
10·0	1·20	2·7
12·0	1·50	4·9
13·0	1·65	7·5
14·0	2·10	12·0
14·8	Upper limit	
Most inflammable mixtures	8 per cent.	10·2 per cent.

Table III.—*Ethane.*

Percentage of gas in air.	Least igniting current.	
	Continuous at 100 volts.	Alternating at 40 ∼ 200 volts.
3·1	Lower limit	
3·5	1·6	12·0
4·5	1·0	7·0
5·0	0·98	6·0
6·0	1·08	4·5
7·0	1·25	4·0
8·0	1·45	4·5
10·0	1·82	10·2
10·7	Upper limit	
Most inflammable mixtures	5·0 per cent.	7·0 per cent.

The curves drawn from the continuous and alternating-current values are quite different in type; the former is chisel-pointed, the latter U-shaped and parabolic at the lowest values. In neither case is the most sensitive mixture that for complete combustion. For continuous currents it is below it, for alternating current above it. The least igniting continuous current is very nearly the same for all the paraffin gases.[4] The influence of ethane is, therefore, not to increase the sensitiveness of the mixture to electrical ignition other than by lowering the limit of inflammability. For alternating circuits ethane actually requires greater currents than methane,[5] and the very great increase in the magnitude of alternating as compared with continuous current is the first and strongest argument in favor of the use of alternating current from the point of view of risks from break sparks.

Influence of Inert Gases.—A small excess percentage of nitrogen appears to have a marked effect on the magnitude of the igniting currents. Pit gas containing from 6 to 12 per cent of nitrogen, diluted with an air to form mixtures having measured percentage of combustible gas, required the igniting currents to be from one and a half to twice as great as with methane when direct currents was used, and to as much as four times greater when alternating currents, at a frequency of 40, were used for ignition[6]. This point requires fuller examination.

Influence of Circuit Voltage.—The change of igniting currents with voltage is not the same in continuous and alternating circuit. In the former the product of voltage and current is approximately constant over part of the working range; in the latter the current does not always diminish as the voltage is raised, but remains constant over a considerable range of it. An alternating pressure of about 500 is the safest in the sense that, at this pressure, a greater power can be broken without ignition than at any other.

Table IV.—*Igniting Currents for a 9·5 per cent. Mixture of Methane and Air.*

Voltage.	Continuous current at 100 volts.	Alternating at different frequencies.			
		40.	60.	80.	100.
50	2·5	16·0	...	...	...
100	1·0	7·0	16·0	20·0	29·0
200	0·4	3·8	12·2	14·2	19·0
300	0·25	3·5	7·0	12·5	17·0
500	0·2	3·5	6·0	11·0	13·0
700	...	3·0	4·5	10·0	10·7
1,000	...	0·75	1·5	5·5	8·0

Thus, at 1,000 volts alternating current at 40 frequency the igniting current is a little less than at 100 continuous volts.

It can be shown that at a frequency of about 100 a break spark ignites gas with more difficulty than at any other frequency. For all circuits other than large power circuits this frequency is to be recommended from the point of view of safety from ignition by break of cable.

Influence of Self-induction in a Circuit.—Inductance in a circuit, either continuous or alternating, increases the igniting action of a break spark. The energy of the circuit which just causes ignition is the same at all inductances from 0.02 to 0.6 henry[7]—that is, the igniting current is inversely proportional to the square root of the inductance in a circuit. This is most important in signaling circuits in which the inductance of a bell may reach 0.5 henry. The igniting current at this for a single break is 0.5 ampere. Bell circuits in which open sparking may occur, may, therefore, be regarded as dangerous unless otherwise protected.

Signaling by Electric Bells.—The voltage for this purpose in Great Britain is limited to 25, but there are no conditions specified as to its source. It is most usually 6 to 15, except on long haulage roads. The working current taken by an ordinary mining signaling

*Paper read before the British Association in Australia.

[1] "The Lower Limit of Inflammation of Mixtures of the Paraffin Hydrocarbons with Air," by R. V. Wheeler and M. J. Burgess, "Trans. Chem. Soc.," 1911, Vol. XCIX., p. 2,013.

[2] "Sur la Combustion des Melanges Gazeux," par. M. M. Taffanel et Le Floch, "Comptes Rendus," Tom. 157, No. 15, October 13th, 1913, 1.595.

[3] "The Ignition of Coal Gas and Methane by Momentary Arcs," by W. M. Thornton, "Trans." Inst. Min. Eng., 1912.

[4] "The Electrical Ignition of Gaseous Mixtures," Roy. Soc. "Proc.," VA., Fig. 2.

[5] *Loc. cit.*, Fig. 12.

[6] "The Comparative Inflammability of Mixtures of Pit Gases Ignited by Momentary Electric Arcs," "Trans." Inst. Min. Eng., Vol. XLVI., part 1, pp. 112-124, 1913.

[7] "The Ignition of Coal-gas and Methane." *Loc. cit.*, Fig. 5.

bell may be from 0.15 to 0.4 ampere. The inductance of a bell changes with the setting of the vibrating armature, and may be from 0.1 to 0.5 henry. These values are large from an ignition point of view, but the ringing force varies as the square of ampere-turns on the windings (and the break spark, either at the tremble contact or the ringing point on the wires, also as the square of the ampere-turns), so that some such figures cannot be avoided; for if the current is less, the turns, and therefore the inductance, are greater. It is, however, possible by shunting the inductance to remove altogether the risk of ignition. Dr. Wheeler's test on the Senghenydd bells gave the following figures:[8]

Mixtures of methane and air were fired by the spark at *the bell trembler* when there was a current of 0.45 ampere passing, and 4.5 volts from secondary batteries having an internal resistance of 0.1 ohm per cell. The bell resistance was 10 ohms, and its mean inductance 0.34 henry. A bell having 0.13 henry inductance required 7.5 volts at 0.7 ampere, with 10 ohms resistance.

No ignition was obtained at the sparks *on the signaling wires* when the voltage was raised to 26 and the current to 1.05 amperes. Shunting the bell coils prevented any ignition up to 24 volts, 1.15 amperes from secondary cells. When wet Leclanché cells are used for ringing, having an internal resistance of 1.5 ohms per cell, the effect is to increase the voltage and current, which can be safely used to beyond the limit of 25 volts allowed by the rules. Since, however, coal gas and air mixtures were ignited with a current of 0.2 ampere passing at 5.5 volts on the bell by sparks on the signaling wires, it would appear that there is not a large margin of safety in ordinary bell circuits. The best bells have very little spark in the bell, but the spark on the wires remains unless the windings are shunted. The actual voltage across the break point, either at the trembler or the wires, is many times greater than the battery voltage, and may approach 200. It has all the qualities of an induction coil discharge, a high voltage with a sharply peaked wave.

Electric Lamps.—Many observations have been made on the ignition of gas by hot filaments, notably by Wullner and Lehmann, Heise and Theim, and Hauser. Recent work at the U. S. A. testing station at Pittsburgh[9] has shown, that for practical purposes, *any modern incandescent lamp* may ignite firedamp if broken in such a manner that the filament is not fractured. The voltage in the lamp is not in itself material, and 2-volt lamps can ignite gas in this way. Small hot-wire lamps are more dangerous than carbon lamps on account of the strength of the filament. On the other hand, the possibility of ignition by fixed and protected lamps, or by portable electric safety lamps, may be regarded as remote compared with that of the open sparks on to the signaling circuits. The spark at the switch in portable safety lamps cannot ignite firedamp; but in a badly constructed lamp there has been ignition of the cell gases. This is, in fact, the most important point to safeguard in portable lamps, the modern forms of which are quite satisfactory.

Ignition by Fuses.—Wullner and Lehmann found that a hot wire appeared to ignite gas at the moment of fusion. This observation is of interest in its bearing on the mechanism of ignition, but for practical purposes it may be said that an open fuse, even for 2-volt circuits, may be regarded as unsafe, though at low voltage ignition is not obtained until a critical current is reached, and the effect depends also upon the ratio of the circuit current to the fusing current of the wire when slowly increased. I have seen bare copper 100-ampere fuses in a haulage house 200 yards from the face in a gassy pit.

Other possible causes of electrical ignition of gas in coal mines are:

Oscillations on Cable Sheaths Due to Surges.—It has been suggested that induced electrostatic oscillations upon the sheath or armoring surrounding a conductor upon which violent oscillations had been momentarily set up by a short-circuit, might have sufficient energy if discharged to an adjoining conductor to ignite gas. I tried this on a length of 200 yards of lead-covered cable, in which a 500-volt short-circuit was made with much power behind it. There were no sparks to be obtained from the sheath, which was insulated from earth, under many conditions of trial, and induction sparks from this cause may be regarded as non-existent or of insufficient energy to be visible in darkness.

Leakage Arcs from Cable Armoring.—When from neglect or breakage the binding of armoring is imperfect, a leakage arc may be set up when a fault develops on the system. The igniting influence of such arcs has several interesting features. It is, in the first place, not much more active in starting ignition than a break spark, the values for continuous-current sparks being as follows:

Table V.—*Iron Poles.*

Continuous voltage.	Least igniting current.	
	Leakage arc.	Break spark.
100	0·95 ampere.	1·05
200	0·37 „	0·55
300	0·13 „	0·31
400	0·05 „	0·20
500	0·02 „	0·10

Below a certain voltage the cooling action of the poles rise so rapidly in importance that large currents are required in order to cause ignition. Another point of interest is that the difference between alternating and continuous currents is now greatly diminished, so that for practical purposes the igniting leakage currents may be taken as the same. A third is that the flattening of the current-voltage curves for alternating current previously noticed is now no longer found. Small leakage arcs are very difficult to maintain even between carefully adjusted poles, so that if a leakage arc does persist in mining practice it will probably have a current in excess of any of these quoted values, and any leakage current above these values may cause a dangerous arc, though the conditions would have to be exceptionally favorable.

Static Discharge Induced by Steam Jets.—At least one fatality is known to have resulted indirectly from shock caused by static discharge from an insulated telephone wire set up by exhaust steam passing across it. The existence of a brush discharge—a "blue glow"—from leaky steam pipes underground has been observed, and the question raised of its possibly igniting gas. I find that gaseous mixtures cannot be fired by such discharge, or by the more active discharge from needle points at high pressure, *unless a definite spark passes.* This can be easily tried in any electrostatic machine. There may be a large brush glow, but there is no ignition at a bunsen burner until a spark passes. Electrostatic glow does not, therefore, appear to be dangerous in itself in coal mining, though when there is high pressure there is always the possibility of sudden spark discharge on the near approach of another conductor. Even in this case I have observed sparks which did not ignite most sensitive explosive mixtures of methane and air; but electrostatic discharge sparks from large surfaces are particularly dangerous and active in starting ignition.

Static Discharge from Belting.—It is well known that sparks can be obtained from high-speed belting. I have compared the nature and appearance of these with those known to ignite gas, and am of opinion that the discharge of electrification appears to be confined to a small part of the inner surface of the belt, and, though it has a pressure often approaching 50,000 volts, yet the energy of discharge is exceedingly feeble and is not necessarily dangerous. I have not succeeded in lighting a bunsen burner by the sparks from a 6-inch belt. The high velocity and disturbance of air in the neighborhood of the belt is unfavorable to ignition of gas, but it would be well to have any record of sparks from this cause which can be obtained in non-fiery mines.

Static Charge Induced by Movement of Clouds of Dust Across a Conductor.—The electrification produced by the formation of a dust cloud of any fine material has recently been demonstrated by Mr. W. A. D. Rudge,[10] and the suggestion made that on the occasion of a fall of rock and with large clouds of coal and stone dust driven along a road, an insulated conductor, such as a girder or signaling wire, might have become sufficiently charged to spark to a neighboring earthed conductor. Sparks of a centimeter long have been produced in this way under favorable conditions; but, though it has been tried by Mr. Rudge, none have so far been obtained underground by movements of coal or stone dust under practical conditions. As a possible cause of gas ignition this cannot, however, be dismissed, and the continued streaming of dust after a fall which may have released gas is favorable to this as a possible, though not highly probable, cause of explosion.

Sparking by Electrification Produced by Grinding Surfaces under Pressure.—Many substances become electrified when heavily squeezed or sheared. At the time of the San Francisco earthquake the crest of a ridge of rocks in which a fault of several feet was developing were seen at night to be illuminated by a blue electrical discharge. Such a state depends greatly on the scale of the phenomenon, and cannot be reproduced in the laboratory; but during the state of shearing stress before a large fall occurs there may be some such action so that at contact between the falling rocks a spark may be set up. This is a suggestion. Dr. Cadman has actually obtained an ignition of gas by contact between falling stones, but the rocks were soaked (naturally) in bituminous matter. These two causes do not, however, affect the use of electricity in mining.

Sparking by "Wireless" Operations on the Surface.—This must be regarded as an impossible cause, for although sparks can be freely obtained between, say, pieces of arc carbon lying on a table in the immediate neighborhood of a sending station, yet they cannot be obtained 100 yards away under pit conditions, and could certainly not be produced underground.

Capacity Sparks in General.—The energy of pure capacity sparks which ignite gas is extremely small. A capacity of 0.05 mfd. charged at 500 volts and discharged between iron poles ignites gas, and as the voltage is diminished the capacity increases in such a manner that the energy is constant at 0.005 joule. Such sparks are obtained from cables the conductors of which have been switched off and left insulated.

Electrical Ignition of Coal Dust with Gas Present.—Two methods were used to determine this important relation.[11] In one the current was found by trial which just ignited a cloud of coal dust in an explosion chamber. In this case the current was so chosen that there were seven ignitions in 100 trials. The chamber was then filled with weak mixtures of methane or of actual pit gas with air and the same current broken. The number of ignitions was increased by the presence of the gas as follows:

Table VI.—*Current 3·5 amperes, 480 volts. Continuous, non-inductive.*

Percentage of methane in air by volume.	Percentage of full ignitions.
0·0	7·0
0·25	10·0
0·50	17·0
0·75	31·0
1·0	53·0
1·25	75·0
1·5	97·0

Above one-half per cent the number of ignitions is directly proportional to the percentage of gas present. When the gaseous mixture was passed in a continuous stream through the chamber at a velocity of about 1 foot a second the number of ignitions was reduced by one half; a still atmosphere is, therefore, favorable to the initiation of dust explosions.

In the second method the *least* current which could ignite the mixture of gas and dust was found by trial.

The nature of the inflammable gas is not of the first importance, for practically the same results were obtained with pit gas or house gas; they did not differ by more than a few per cent. It will be seen from Table VII that it is again at one half per cent that the influence of the gas begins to be marked.

Table VII.

Percentage of gas in air.	Least igniting continuous current.	
	240 volts.	480 volts.
0·0	16·0	3·5
0·5	12·0	3·0
0·75	7·5	2·0
1·0	4·75	1·5
1·5	3·4	1·0
2·0	2·7	0·8

Though the gas at these percentages could not maintain self-ignition alone it is burnt in explosion, and clearly helps to bridge the space between the dust particles. The dust is, however, the more important combustible element for the cross curves from Table VII, with volts as abscissa instead of percentage of gas, fit under the dust-ignition curve and not the gas curve.

The new rules under the Coal Mines Act of 1911 prohibit the use of electricity where more than 1.5 per cent of gas is present, a very fair comparison having regard to initiation of explosions; but it should be known that smaller quantities help to transmit an explosion where dust is present, and the campaign against coal dust should aim at prevention rather than treatment by inert substances.

Electrical Ignition of Coal Dust alone.—All fine dusts of combustible matter can be ignited by the streaming sparks of flaming induction coil discharge,[12] but in mining work the arcs formed are almost always momentary. The ignition of clouds of coal dust by quick break arcs was, therefore, examined in detail,[13] some of the results are given in Table VIII.

Table VIII.—*Least Igniting Currents of Clouds of Durham Coal Dust.*

Volts.	Least current causing ignition.		Ratio.
	Continuous.	Alternating 40 ∼.	
100	70	120·0	1·7
240	11–16	38·0	3·0
275	9·0	32·0	3·5
480	3·5–5·8	14·0	3·0
635	...	5·2	...
1,000	...	3·3	...

Ignition of coal dust is, therefore, more difficult with alternating than continuous, and in this it is similar to

[8] Report of the Chief Inspector of Mines on the Senghenydd Explosion, p. 36.

[9] U. S. A. Department of Mines. Bulletins and Technical ... of Electricity in Mines.

[10] W. A. D. Rudge, "Nature," February 12th, 1914, Roy. Soc. "Proc."

[11] "The Influence of the Presence of Gas upon the Inflammability of Coal Dust in Air," by W. M. Thornton, British Association, Birmingham, September 11th, 1913. "The Colliery Guardian," September 19th, 1913.

[12] *See* the reports of the Home Office Committee on Coal Dust Explosion.

[13] "The Ignition of Coal Dust by Single Electric Flashes," by W. M. Thornton and E. Bowden. "Trans." Inst. M. Eng., Vol. XXXIX., part 2.

gas alone. At the higher voltages the duration of the alternating current are increases, and the risks of ignition become more equal.

Bitumen Cables.—Attention has been recently called[14] to a risk of explosion from the gases given off by bitumen cables at a developing fault on continuous-current circuits. Such faults are greatly increased by electrical endosmose; *with alternating current no such action occurs.* This was shown recently by burying two[15] bitumen cables in wet earth with the copper conductors bared for one half inch. To one of them continuous voltage at 240 was applied for several days, to another the same alternating voltage at a frequency of 40, and records were taken of the leakage currents. That on the continuous cable increased and reached 6 amperes when cut off. The alternating leakage fell rapidly to a minimum of 0.2 ampere. At the end of the trial the continuous-current insulation was found to be broken up and disintegrated for 2 feet each way from the fault; the alternating-current cable showed not the slightest sign of heating or damage. The reason for this is that moisture is carried along by an electric current, and therefore enters a continuous-current negative cable fault, collecting in the ground around it, penetrating to the conductor and lowering its insulation, and sometimes flooding it for many yards. With alternating current the rapid movement of the moisture to and fro under the action of the current dries the fault up by its own friction, and maintains it automatically cured. There is no case on record of gas explosion from an alternating-current cable fault.

Conclusions.—There is no danger from gas alone under about 5½ per cent of gas in air; but, to give a higher margin of safety the use of electricity must be discontinued when there is more than 1½ per cent, a factor of safety of 3.6.

Lighting Circuits.—The least igniting currents found are such that the break of any continuous current might fire gas, but not of alternating current. For instance, in parallel lighting the current for a single 100-watt lamp may ignite gas—with alternating at 40 ~ seven such lamps, and at 100 ~ 29 lamps. All continuous-current series lighting at 500 volts may ignite gas, but alternating never by a single break. Lamps, large or small, must have complete mechanical protection, and lighting cables should be armored.

Signaling Circuits.—Any bell working by make and break may ignite firedamp at the bell under normal conditions, and at the signaling wires under exceptional conditions of inductance in the bell. Coal gas and air mixtures can be ignited under normal conditions by the signal-wires spark. The factor of safety is, therefore, not large. Risk can be removed by modifying the electrical connections in the bell.

Power Circuits.—In 8 per cent mixtures a continuous current power of 1/10 kilowatt in the lower limit; with alternating current 0.54 kilowatt is a 10 per cent mixture at 40 periods. Leakage arcs are only to be regarded as dangerous just before the system breaks down. Armoring is necessary if break sparks are to be avoided, and careful bonding if leakage arcs are not to occur. In general, it is necessary to prevent the possibility of open sparking, though alternating currents may have a large break spark and yet not ignite gas. If the use of electricity is placed under the same controling conditions everywhere as in naked light mines, and always regarded as a possible source of ignition unless the parts are completely protected with metallic armoring and covers, all dangers can be met and guarded against. The risks are even now no greater than those attending the use of flame safety lamps, which in almost every great disaster have been discussed as a possible cause of the original ignition.

The object of the series of researches of which this paper is an abstract is to bring to the consideration of those who are still doubtful that these risks exist, experimental evidence that they are real, and to give the limits at which safety begins.

[14] "A case of Gaseous Explosion caused by the Electric Heating of Bitumen in Cable Troughs," by W. M. Thornton and J. A. Smythe. *The Electrician*, August 22, 1913.

[15] Home Office report on Explosions from Bitumen Cables, 1914.

A Four-Thousand-Year Calendar*

It is often desired to know on what day of the week some event occurred, but to ascertain this often requires considerable time and trouble. To meet the situation a calendar has been arranged by Mr. S. F. Kennedy, of Lakeview, Mich., which enables the question to be answered almost immediately for any event, ancient or modern, by a simple reference to the tables given. This calendar covers four thousand years, beginning with the year 1, A.D., so that it will be generally useful for many years to come.

Example 1. The Johnstown flood occurred May 31st, 1889. What day of the week was this? In the table of "Centuries" against 1800 we find the letter *c*. In the first section of the tables find the figure 98, and follow this line across to the column under May, and take the small figure in the column *c*, which is 3. Add this figure to the day of the month, 31 in this case, making 34. In the last column of the tables, at the right, this number is found against Friday, which is the day required.

Example 2. Columbus discovered America October 12th, 1492. Proceed the same as before, but in this case we find two letters, *c* and *d*, against the century, 1400, and as the required date comes in the "Julian" calendar, we take the figure from the column under the second letter, *d*, in the October columns. This is 4, which, added to the day of the month, 12, gives us 16, which is found to be Monday. If the date had been in the "Gregorian" calendar the figure under the first letter would have been taken.

Example 3. Beginning of the Christian era, January 1st, 0. What day was this? In the century table against 0 we find the letters *a*, *b*, and as the event was in the "Julian" calendar we take the figure under the second letter, *b*, for January, which is 5. Adding this to the day of the week gives us 6, which corresponds to Friday.

*Copyrighted January 30th, 1913, by S. F. Kennedy, Lakeview, Mich.

0 TO 4000 YEARS				JAN. a	b	c	d	FEB. a	b	c	d	MAR. a	b	c	d	APR. a	b	c	d	MAY a	b	c	d	JUNE a	b	c	d
0				6	5	3	1	2	1	6	4	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5
1	29	57	85	1	6	4	2	4	2	0	5	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6
2	30	58	86	2	0	5	3	5	3	1	6	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0
3	31	59	87	3	1	6	4	6	4	2	0	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1
4	32	60	88	4	2	0	5	0	5	3	1	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3
5	33	61	89	6	4	2	0	2	0	5	3	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4
6	34	62	90	0	5	3	1	3	1	6	4	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5
7	35	63	91	1	6	4	2	4	2	0	5	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6
8	36	64	92	2	0	5	3	5	3	1	6	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1
9	37	65	93	4	2	0	5	0	5	3	1	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2
10	38	66	94	5	3	1	6	1	6	4	2	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3
11	39	67	95	6	4	2	0	2	0	5	3	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4
12	40	68	96	0	5	3	1	3	1	6	4	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6
13	41	69	97	2	0	5	3	5	3	1	6	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0
14	42	70	98	3	1	6	4	6	4	2	0	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1
15	43	71	99	4	2	0	5	0	5	3	1	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2
16	44	72		5	3	1	6	1	6	4	2	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4
17	45	73		0	5	3	1	3	1	6	4	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5
18	46	74		1	6	4	2	4	2	0	5	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6
19	47	75		2	0	5	3	5	3	1	6	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0
20	48	76		3	1	6	4	6	4	2	0	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2
21	49	77		5	3	1	6	1	6	4	2	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3
22	50	78		6	4	2	0	2	0	5	3	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4
23	51	79		0	5	3	1	3	1	6	4	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5
24	52	80		1	6	4	2	4	2	0	5	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0
25	53	81		3	1	6	4	6	4	2	0	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1
26	54	82		4	2	0	5	0	5	3	1	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2
27	55	83		5	3	1	6	1	6	4	2	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3
28	56	84		6	4	2	0	2	0	5	3	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5

0 TO 4000 YEARS				JULY a	b	c	d	AUG. a	b	c	d	SEP. a	b	c	d	OCT. a	b	c	d	NOV. a	b	c	d	DEC. a	b	c	d
0				6	4	2	0	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4	5	3	1	6
1	29	57	85	0	5	3	1	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5	6	4	2	0
2	30	58	86	1	6	4	2	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6	0	5	3	1
3	31	59	87	2	0	5	3	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0	1	6	4	2
4	32	60	88	4	2	0	5	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2	3	1	6	4
5	33	61	89	5	3	1	6	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3	4	2	0	5
6	34	62	90	6	4	2	0	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4	5	3	1	6
7	35	63	91	0	5	3	1	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5	6	4	2	0
8	36	64	92	2	0	5	3	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0	1	6	4	2
9	37	65	93	3	1	6	4	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1	2	0	5	3
10	38	66	94	4	2	0	5	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2	3	1	6	4
11	39	67	95	5	3	1	6	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3	4	2	0	5
12	40	68	96	0	5	3	1	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5	6	4	2	0
13	41	69	97	1	6	4	2	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6	0	5	3	1
14	42	70	98	2	0	5	3	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0	1	6	4	2
15	43	71	99	3	1	6	4	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1	2	0	5	3
16	44	72		5	3	1	6	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3	4	2	0	5
17	45	73		6	4	2	0	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4	5	3	1	6
18	46	74		0	5	3	1	3	1	6	4	6	4	2	0	1	6	4	2	4	2	0	5	6	4	2	0
19	47	75		1	6	4	2	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6	0	5	3	1
20	48	76		3	1	6	4	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1	2	0	5	3
21	49	77		4	2	0	5	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2	3	1	6	4
22	50	78		5	3	1	6	1	6	4	2	4	2	0	5	6	4	2	0	2	0	5	3	4	2	0	5
23	51	79		6	4	2	0	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4	5	3	1	6
24	52	80		1	6	4	2	4	2	0	5	0	5	3	1	2	0	5	3	5	3	1	6	0	5	3	1
25	53	81		2	0	5	3	5	3	1	6	1	6	4	2	3	1	6	4	6	4	2	0	1	6	4	2
26	54	82		3	1	6	4	6	4	2	0	2	0	5	3	4	2	0	5	0	5	3	1	2	0	5	3
27	55	83		4	2	0	5	0	5	3	1	3	1	6	4	5	3	1	6	1	6	4	2	3	1	6	4
28	56	84		6	4	2	0	2	0	5	3	5	3	1	6	0	5	3	1	3	1	6	4	5	3	1	6

1 Su.	2 Mo.	3 Tu.	4 We.	5 Th.	6 Fr.	7 Sa.	8 Su.	9 Mo.	10 Tu.	11 We.	12 Th.	13 Fr.	14 Sa.	15 Su.	16 Mo.	17 Tu.	18 We.	19 Th.	20 Fr.	21 Sa.	22 Su.	23 Mo.	24 Tu.	25 We.	26 Th.	27 Fr.	28 Sa.	29 Su.	30 Mo.	31 Tu.	32 We.	33 Th.	34 Fr.	35 Sa.	36 Su.	37 Mo.

CENTURIES.

0–a, b.	400–a, b.	800–a, b.	1200–a, b.	1600–a, b.	2000–a, b.	2400–a.	2800–a.	3200–a.	3600–a.
100–b, c.	500–b, c.	900–b, c.	1300–b, c.	1700–b, c.	2100–b.	2500–b.	2900–b.	3300–b.	3700–b.
200–c, d.	600–c, d.	1000–c, d.	1400–c, d.	1800–c.	2200–c.	2600–c.	3000–c.	3400–c.	3800–c.
300–d, a.	700–d, a.	1100–d, a.	1500–d, a.	1900–d.	2300–d.	2700–d.	3100–d.	3500–d.	3900–d.
									4000–a.

EXPLANATION:—Opposite the given year, under the given month, in Century Column, is a little figure which added to the given day of the month at once gives the day of the week in right hand column.

September 2nd, 1752, and all prior dates are reckoned by the "Julian Calendar" and second century letter must be taken. In the present ("Gregorian Calendar") take first century letter.

A Christian University in Cairo.—A fund of $2,000,000 one-tenth of which has already been subscribed, is now being raised in the United States for the purpose of establishing a Christian University, modeled after universities in this country, in Cairo, which is the intellectual center of the Moslem world, and is already the seat of the most famous ot Moslem universities.

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